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Washington, D. C. August, 1924

STUDIES OF THE MEXICAN BEAN BEETLE IN THE SOUTHEAST

By

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Truck Crop Insect Investigations, Bureau of Entomology

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STUDIES OF THE MEXICAN BEAN BEETLE[1] IN THE SOUTHEAST.[2]

By Neale F. Howard, *Entomologist*, and L. L. English, *Junior Entomologist, Truck Crop Insect Investigations, Bureau of Entomology.*

CONTENTS.

INTRODUCTION.

Wherever it occurs the Mexican bean beetle is by far the most serious enemy of beans. It has been known for about 75 years in the Southwest, where it has undoubtedly been established for a longer period. It was long ago reported that in Colorado its possibilities as a pest were greater than those of the Colorado potato beetle. In many sections in the Southeast it is often the determining factor in the growing of beans.

The original home of this beetle is southern North America. It occurs in many parts of Mexico and in Guatemala.

The species was first discovered in the Southeast in 1920, when specimens were received at the Alabama Experiment Station from Blocton and Birmingham, Ala. Authentic reports by various growers indicate that the insect was not at all uncommon about Birmingham in 1919, and it is presumed that it reached Alabama at least as early as 1918.

It has been pointed out by Dr. W. E. Hinds that during the recent European war large shipments of alfalfa hay from the West were received in northern Alabama, and it is possible that the insect was introduced with these shipments, the infestation originating from the Southwest rather than from Mexico. In 1921 the insect was reported from Thomasville, Ga., by S. E. McClendon, the infestation indicating the presence of the beetle there for at least one year before that time.

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[1] *Epilachna corrupta* Muls.; order Coleoptera, family Coccinellidae.

[2] Report on research investigations on the Mexican bean beetle conducted during the years 1921 and 1922. During 1921 the project was carried on cooperatively with the Alabama Experiment Station.

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By the fall of 1920 the bean crop about Birmingham and Blocton Ala., was destroyed by the bean beetle. In 1921 the infestation was extremely severe, and most of the early bean crop was destroyed.

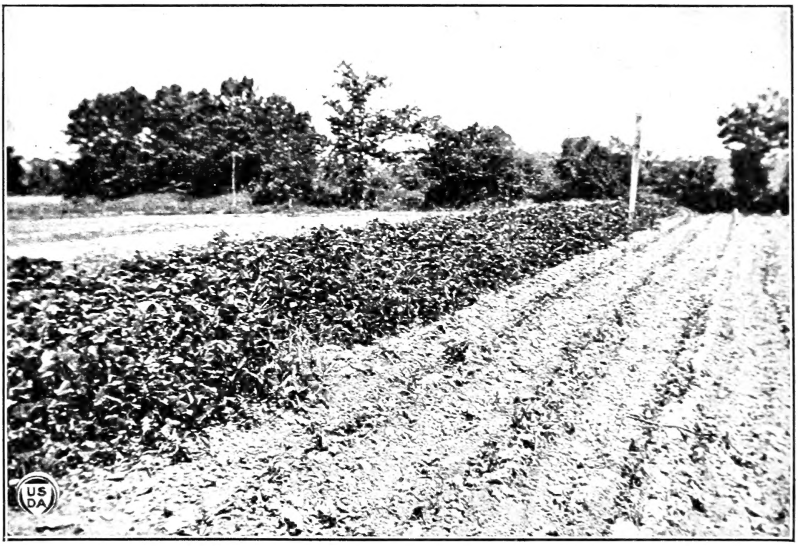


FIG. 1.—Bush snap beans destroyed by the Mexican bean beetle at Birmingham, Ala. Velvet beans adjacent were not attacked.

By August 1 there was hardly a bean field in bearing near Birmingham. (Pl. I, *A*, *B*.) Reports of severe damage came also from other points in northern Alabama.

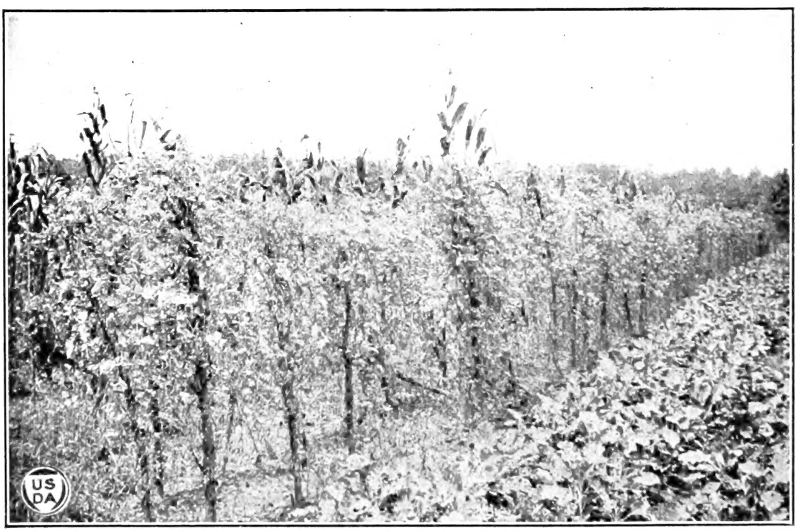


FIG. 2.—Destruction of pole lima beans by the Mexican bean beetle at Birmingham, Ala.

In 1921 the price of snap beans and Lima beans rose to unusual levels on the Birmingham markets, owing to the practical destruction by this insect of bean plantings in the district. At Chattanooga,

Tenn., where the insect was not known to occur until 1921, the same situation occurred in 1922, one year after the insect reached that region. (Figs. 1, 2.) By the fall of 1922 practically no beans were growing about Chattanooga. Serious damage also occurred about Atlanta and other points in northern Georgia, and in many sections of eastern Tennessee.

DESCRIPTION.

The Mexican bean beetle is a robust, hard-shelled insect of hemispherical form bearing eight black spots on each elytron or wing cover. (Fig. 3; Pl. II, *A*.) Typical adults measure about one-fourth to five-sixteenths inch in length and one-fifth to one-fourth

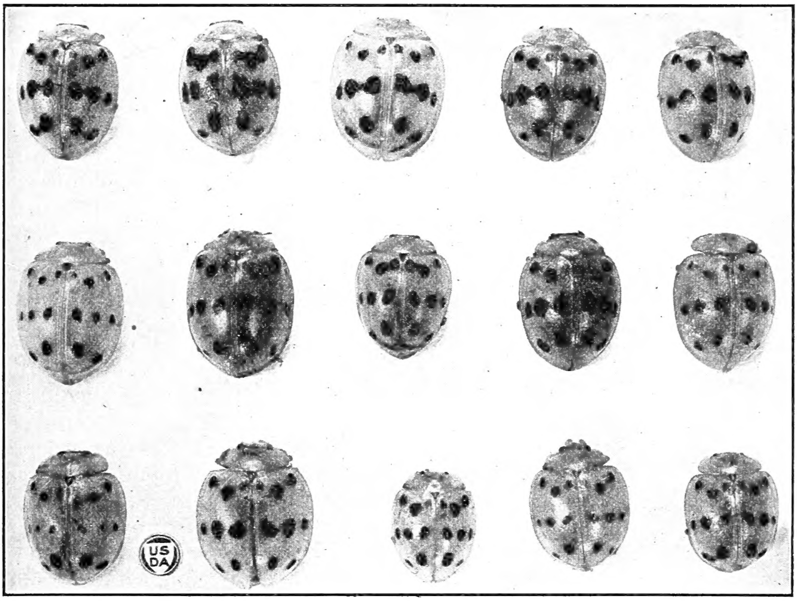


FIG. 3.—Adults of the Mexican bean beetle, showing variations in size and marking.

inch in width, and when fully mature are copper-colored. Newly emerged specimens are light lemon yellow. Males are distinguished from females by a notch in the posterior abdominal segment, this notch being absent in the females. Males average slightly smaller, but many are as large as females.

The eggs are small, about one-twentieth of an inch long, orange-colored, and are laid in masses of from 40 to 60 on the under sides of the bean leaves.

The larvæ, on hatching from the eggs, are orange-colored, and are covered with long branched spines. (Fig. 4; Pl. I, *A*.) They grow rapidly and become about one-third inch long and half as wide before pupation takes place. (Pl. II, *B*.)

The pupa is almost the size of the beetle, is yellow, and is attached to the leaf or object on which it pupates by the last larval skin, which is white and spiny and covers the posterior abdominal segments. (Pl. III, *A*, *B*.)

The Mexican bean beetle belongs to the family Coccinellidæ, or lady-birds, and all the known species in this country are beneficial except the insect under discussion and the squash lady-beetle (*Epilachna borealis* Fab.). The Mexican bean beetle has never been known to eat other insects, and it resembles more closely in many ways the family of leaf-eating beetles, or Chrysomelidæ, than the Coccinellidæ.

DISTRIBUTION.[3]

The rapid spread of the Mexican bean beetle since its introduction into the Southeast has been remarkable. In 1920, late in the summer, Dr. W. E. Hinds and coworkers found 13 counties infested in northern Alabama. In 1921 a rapid spread in all directions took place, especially to the northeast. By fall the insect was found in portions of six States, over an area of approximately 40,000 square miles, as compared with 4,500 square miles infested the previous year. The distribution in 1922 in the Southeast, so far as known, covered at least 70,000 square miles in seven States. (See map, fig. 5.)

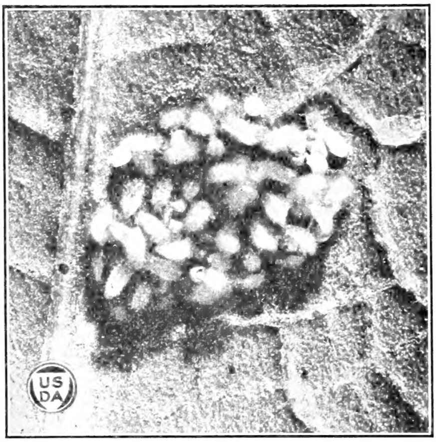


FIG. 4.—Young larvæ of the Mexican bean beetle clinging to eggshells a short time after hatching.

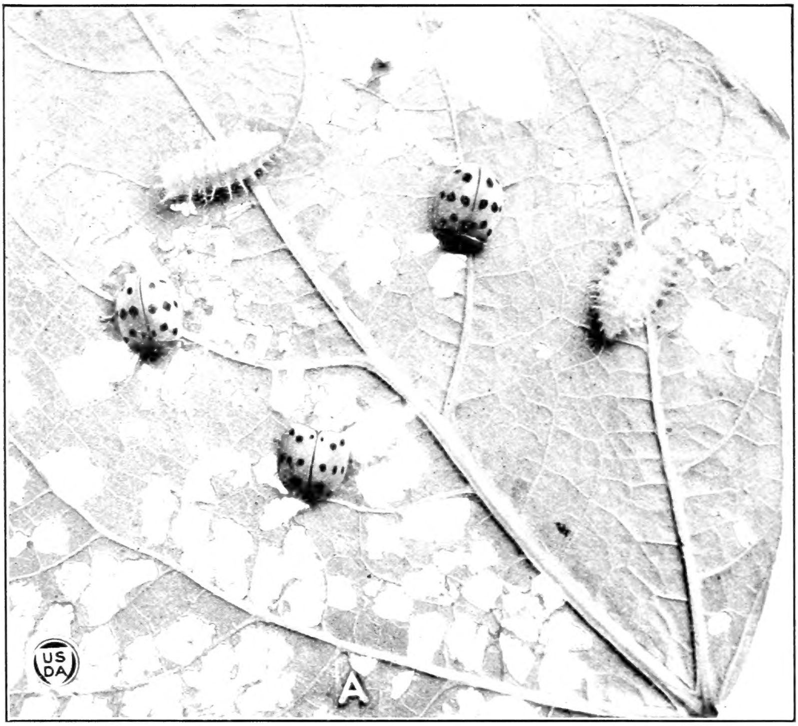
An isolated infestation was reported in 1921 at Thomasville, Ga., near the Florida line. This infestation covered 14 square miles. No appreciable spread in this locality occurred during 1922, only 3 additional square miles being infested.

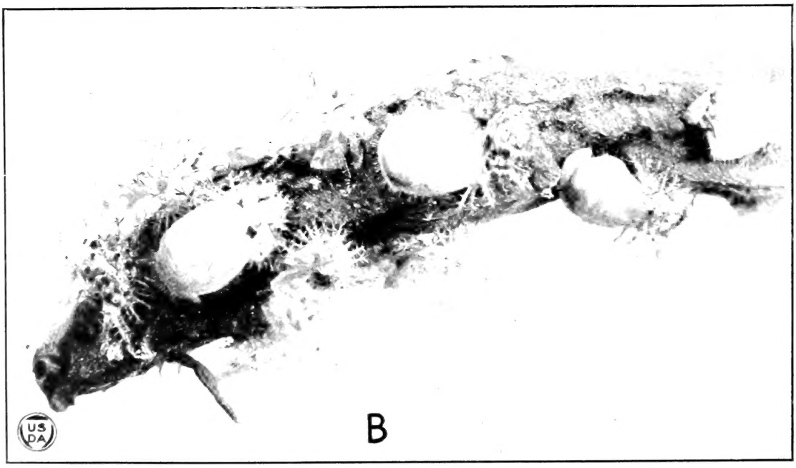
The spread in general has been decidedly to the north. In the fall of 1920 the most northern locality found to be infested was Dekalb County, Ala. One year later the infestation had reached Whitley and McCreary Counties, Ky., Hawkins County, Tenn., and Greenville County, S. C., all of which points are more than 200 miles from Dekalb County, Ala. In 1922 this rapid spread continued, and the insect traversed an area 110 miles across to the northwest at its widest point, viz, from Whitley and McCreary Counties to Bullitt County, Ky. No records are available and no scouting was done in eastern Kentucky. It is certain, however, that the insect is present at least over the territory southeast of Madison, Jackson and Clay Counties. Fayette County, Ky., and Lee and Scott Counties, Va., were scouted by the Bureau of Entomology and found to be infested.

[3] Since this paper was prepared new records of spread have been received, chiefly through the cooperation of entomologists in the States concerned. The beetle is now present in the following localities in addition to those mentioned above: Ross, Gallia, Jackson, Adams, Highland, Pike, Scioto, and Franklin Counties, Ohio; Ashe, Avery, Burke, Cleveland, Gaston, Lincoln, McDowell, Polk, Rutherford, Watauga, Buncombe, Madison, and Yancey Counties, N. C.; Abbeville, Cherokee, and Spartanburg Counties, S. C.; Lamar County, Ga.; Washington and Unicoi Counties, Tenn.; Lee County, Ala.; Tishomingo and Itawamba Counties, Miss.; Spencer, Meade, Letcher, Laurel, Bell, Clay, Estill, Harlan, Leslie, Ousley, and Perry Counties, Ky.; and Russell and Wise Counties, Va.

DAMAGE DONE BY THE MEXICAN BEAN BEETLE

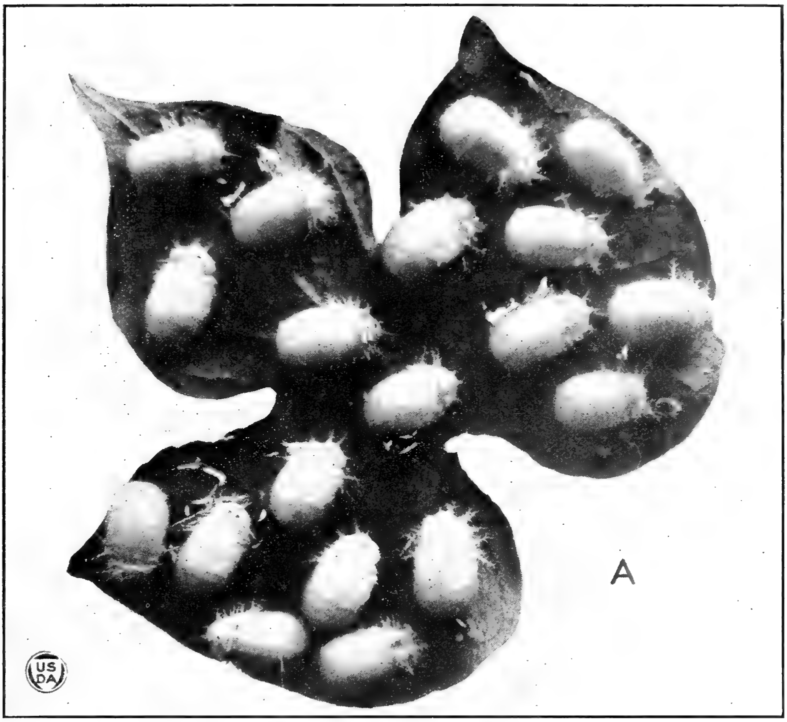
A, Field of pole Lima beans destroyed, Birmingham, Ala., 1922; *B*, bush Lima beans destroyed, Birmingham, Ala., September, 1921

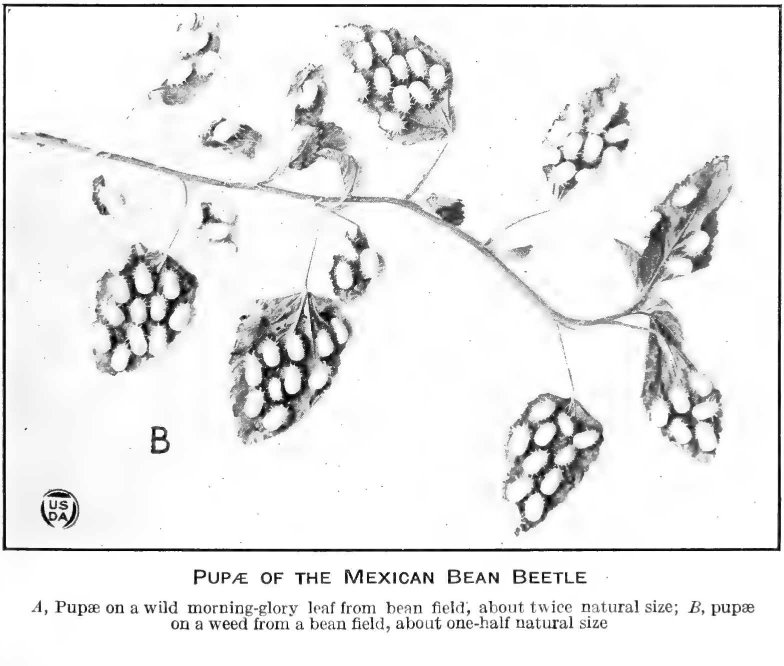




ADULTS, LARVÆ, AND PUPÆ OF THE MEXICAN BEAN BEETLE

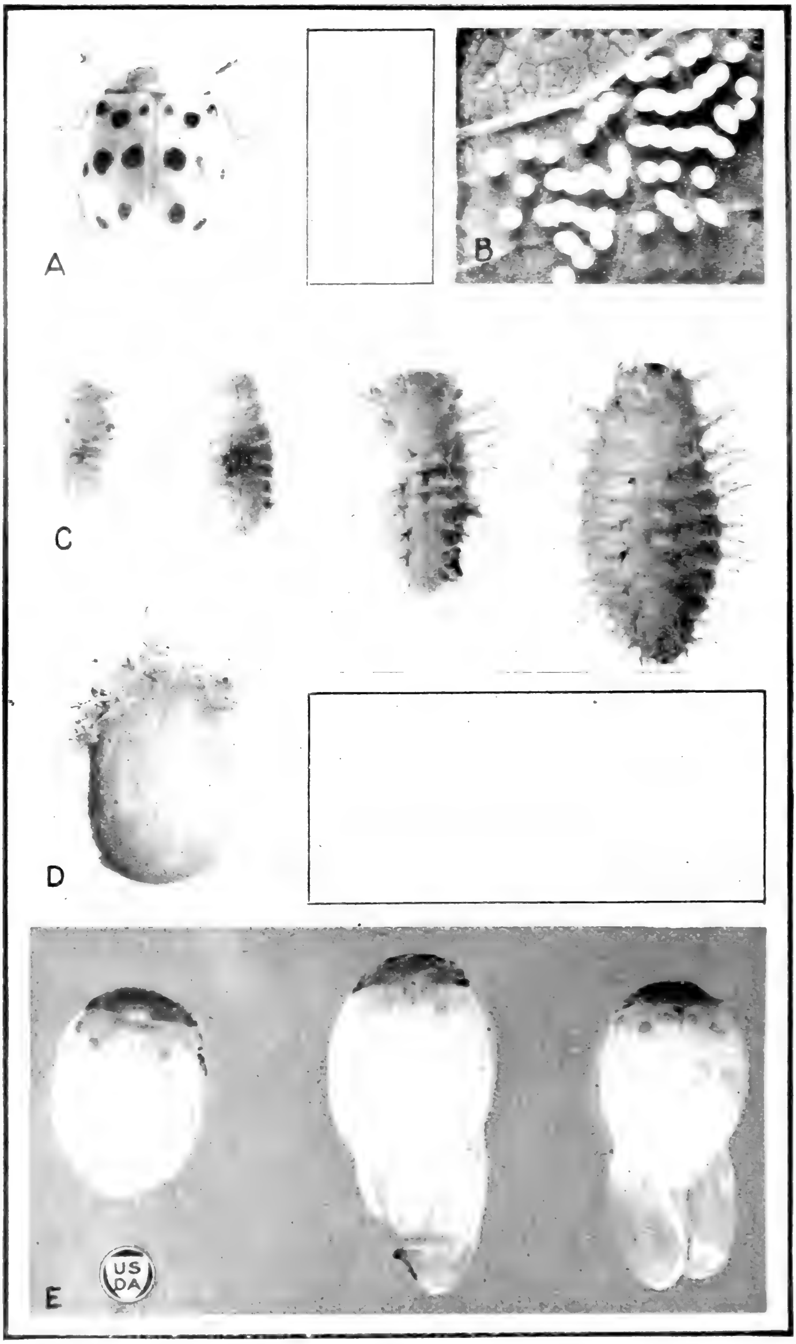
A, Adults and fourth-stage larvæ on a bean leaf; *B*, pupæ and pupal skins on a bean pod. Considerably enlarged





PUPÆ OF THE MEXICAN BEAN BEETLE

A, Pupæ on a wild morning-glory leaf from bean field, about twice natural size; *B*, pupæ on a weed from a bean field, about one-half natural size



STAGES OF THE MEXICAN BEAN BEETLE

A, Adult; *B*, egg mass; *C*, four larval stages; *D*, pupa; *E*, adults shortly after transformation from pupæ. All slightly over four times natural size

NATURAL SPREAD.

The Mexican bean beetle is capable of long flights. In the western part of the United States it must necessarily fly long distances to suitable hibernation quarters. In its newer habitat in the Southeast it migrates throughout the season, but especially in spring and fall. Experiments with marked beetles show that a flight of 5 miles is possible within two days and flights up to $3\frac{1}{2}$ miles are common. Records of the spread in the Southeast indicate that much greater distances than these are traversed with ease.

Many other natural factors, of course, may contribute to the remarkable spread of the beetle, among them being air currents and

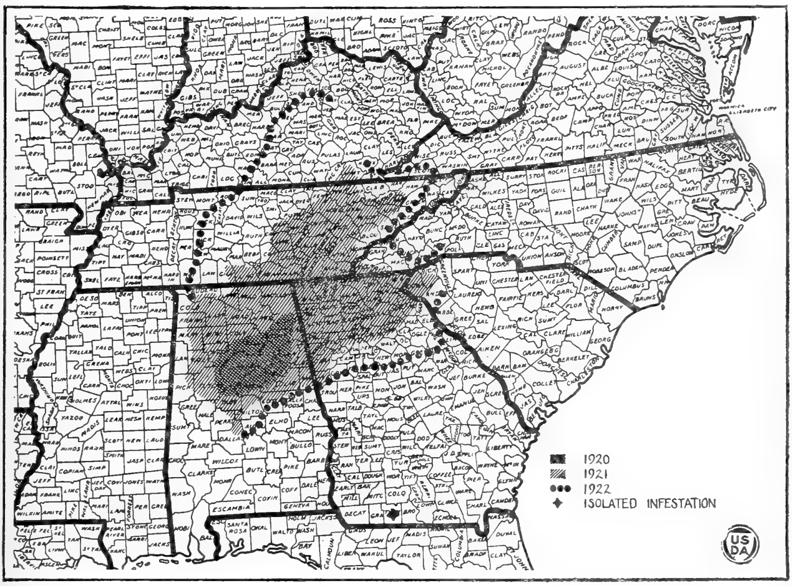


FIG. 5.—Map showing known distribution and spread of the Mexican bean beetle in the Southeast to December, 1922. The map was prepared from records obtained through the cooperation of State entomologists and others in the States concerned and chiefly from scouting done by the Bureau of Entomology under the direction of J. E. Graf and the senior author.

flood waters. It is believed, however, that the spread northward is attributable to the fact that the Mexican bean beetle is a northern Transition or sub-Boreal form, or at least is searching for conditions similar to those found in the higher altitudes of the Southwest and the Mexican plateau. No appreciable spread to the south in Alabama or south from Thomasville, Ga., nor any spread west into Mississippi, occurred during 1922. The damage to the bean crop in many instances has been extremely severe the second year after the insect has reached a new district of approximately the same latitude as Birmingham, Ala., or farther north. No reports of persistent, severe injury have come from southern points. Great damage occurred at Chattanooga, Tenn., and Atlanta, Ga., in 1922, one year after the beetle was known to have reached these places.

LIFE HISTORY AND HABITS.

The adult (Pl. IV, *A*) begins to feed immediately on arrival in the bean field from winter quarters. Females may begin to lay eggs 8 days after emergence from hibernation and possibly sooner, but the majority feed for a longer period, the average time being 14 days for 6 females in 1922. The adult feeds on the under surface, usually puncturing the leaf and leaving ragged holes, some very small, others one-fourth inch across. Only a very small percentage of feeding takes place on the upper surface.

Mating occurs in most cases in the fall, but also in the spring. The abdomen of the gravid female gradually becomes distended, and is noticeably enlarged 24 hours before oviposition. Females are then easily distinguished from males. An individual female has deposited as many as 1,669 eggs during a season. Eggs are usually laid in groups of from 40 to 60, averaging 51 for females observed by the writers in 1921 and 1922. Eggs (Pl. IV, *B*) are almost invariably placed on the under surface of the leaves in rather compact groups. In midseason a female will deposit a group of eggs quite regularly every two or three days until death.

The egg-laying records of a few representative females chosen from 69 complete experiments in 1921 and 1922 are given in Table 1. Included also is the time between emergence and the first egg laying. The beetles of the fourth generation did not lay eggs. The records of mating are the observations made while attending to the experiments and are not complete. Each experiment included a male and female, except in the cases noted.

TABLE 1.—*Egg deposition records of a few representative females of the Mexican bean beetle in cages, Birmingham, Ala., 1921 and 1922.*

1921.

OVERWINTERED FEMALES.

No. LH-9: Female collected in field March 26; more than 10 days between emergence and first eggs.

	Eggs.		Eggs.		Eggs.
Apr. 5	68	May 12	60	May 28	58
8	72	15	55	31	53
14	74	17	60	June 3	52
21	48	20	53	7	31
26	68	23	64		
30	72	25	54	Total	1,005
May 9	63				

No. LH4-2: Female [1] dormant from hibernation cage March 24; 42 days between removal and first eggs.

	Eggs.		Eggs.		Eggs.
May 5	61	May 24	57	June 6	54
13	56	26	58	9	57
18	57	29	58		
22	56	June 1	58	Total	572

FIRST GENERATION FEMALES.

No. LH-4G: Female emerged May 20; 11 days between emergence and first eggs.

	Eggs.		Eggs.		Eggs.
May 31	47	June 21	54	July 6	55
June 4	41	22	57	8	51
7	53	26	53	11	54
9	52	28 [2]	56	13	54
13	59	30	53		
15	55	July 2	54	Total	1,013
17	55	3 [2]			
19	55	5	55		

[1] This female had no opportunity to mate in 1921. All groups deposited were normally fertile.
[2] Mating observed this date. Females paired when emerged except in case of LH-9 and LH4-2, 1921, which were isolated.

TABLE 1.—*Egg deposition records of a few representative females of the Mexican bean beetle in cages, Birmingham, Ala., 1921 and 1922*—Continued.

1921—Continued.

FIRST GENERATION FEMALES—Continued.

No. LH-2G: Female emerged May 19; 16 days between emergence and first eggs.

	Eggs.		Eggs.		Eggs.
June 4	56	June 17	54	June 27	58
8	55	19	55	28	54
9	53	21	54	30	56
11	56	22	58	July 1	58
13	56	23	53		
15	56	25	47	Total	879

SECOND GENERATION FEMALES.

No. LH-1G2: Female emerged July 5; 6 days between emergence and first eggs.

	Eggs.		Eggs.		Eggs.
July 11 [2]	49	July 22 [2]		Aug. 2	59
11	56	23 [2]	59	5	59
13	60	25	59	6	58
14 [2]		27	57	8	62
15	60	28	60	10	57
17	65	30	57		
19 [2]	58	Aug. 1	60	Total	1,032
21	37				

No. LH-5G2: Female emerged July 16; 7 days between emergence and first eggs.

	Eggs.		Eggs.		Eggs.
July 21 [2]	..	Aug 11	48	Aug. 30	46
22 [2]	..	12 [2]	..	31	46
23 [2]	60	13	46	Sept. 1	44
25	31	14	47	5	91
27	61	16	48	6	47
29	47	17	56	8	28
30	51	18	47	10	66
Aug. 2	28	20	46	13	43
2	68	22	48	14	55
5	47	23	46	17	47
6	48	24	44	20	46
8	49	26	49		
10	48	29	47	Total	1,669

THIRD GENERATION FEMALES.

No. LH-2G3: Female emerged August 8; 6 days between emergence and first eggs.

	Eggs.		Eggs.		Eggs.
Aug. 14	63	Aug. 22	61	Aug. 31	61
15 [2]	..	24 [2]	..	Sept. 1	58
16 [2]	..	25	62	3	61
17	60	26 [2]	..	5	60
18	61	27	57	8	59
19 [2]	..	29	61		
21	51	30 [2]	..	Total	775

No. LH-7G3: Female emerged September 1; 11 days between emergence and first eggs.

	Eggs.		Eggs.		Eggs.
Sept. 12	75	Sept. 22	66	Oct. 11	66
13	62	23	65	21	56
15	64	26	41	29	73
17 [2]	68	28	67		
19	60	30	63	Total	955
19	66	Oct. 3	63		

1922.

OVERWINTERED FEMALES.

No. LH-8 [3]: Female emerged from hibernation cage April 4; 10 days between emergence and first eggs.

	Eggs.		Eggs.		Eggs.
Apr. 14	32	Apr. 24	29	May 4	30
15 [2]	..	26 [2]	..	9	29
17	29	27	36		
20	29	May 3	27	Total	241

[2] Mating observed this date. Females paired when emerged except in case of LH-9 and LH4-2, 1921, which were isolated.
[3] Pair from third generation, 1921.

TABLE 1.—*Egg deposition records of a few representative females of the Mexican bean beetle in cages, Birmingham, Ala., 1921 and 1922*—Continued.

1922—Continued.

OVERWINTERED FEMALES—Continued.

No. LH-16: Female emerged from hibernation cage April 5; 20 days between emergence and first eggs.

	Eggs.		Eggs.		Eggs.
Apr. 25	73	May 31	71	June 17	56
May 1	55	June 3	50	23	19
6	50	7	59		58
9	75	9	59		
15	67	12	57	Total	821
22	72				

FIRST GENERATION FEMALES.

No. LH-3G: Female emerged June 4; 11 days between emergence and first eggs.

	Eggs.		Eggs.		Eggs.
June 15	29	July 12[2]	..	July 23	52
22	55	13	54	27	14
July 5	7	15[2]	..	28	35
6[2]	..	17	32	Aug. 1	56
8	54	20	51		
11	58	22[2]	..	Total	497

No. LH-5G: Female emerged June 5; 14 days between emergence and first eggs.

	Eggs.		Eggs.		Eggs.
June 19	55	July 11	63	July 18	54
July 4	57	14	59		
8	57			Total	345

SECOND GENERATION FEMALES.

No. LH-3G2: Female emerged July 19; 10 days between emergence and first eggs.

	Eggs.		Eggs.		Eggs.
July 29	43	Aug. 14	57	Aug. 29	50
Aug. 1	54	17	54	Sept. 1	55
3	53	18	59	3	55
6	54	21	57	6	55
9	52	25	23		
12	50	27	55	Total	826

No. LH-5G2: Female emerged July 24; 8 days between emergence and first eggs.

	Eggs.		Eggs.		Eggs.
Aug. 1	41	Aug. 18	55	Sept. 6[2]	..
2	60	20	61	7	60
5	60	22	62	9	60
7	64	24	63	17	50
9	65	26	64	18[2]	..
12	40	29	60	20	61
14	62	Sept. 1	51	27	52
15[2]	..	3	62		
17[2]	..	5	61	Total	1,214

THIRD GENERATION FEMALES.

No. LH-2G3: Female emerged August 26; 14 days between emergence and first eggs.

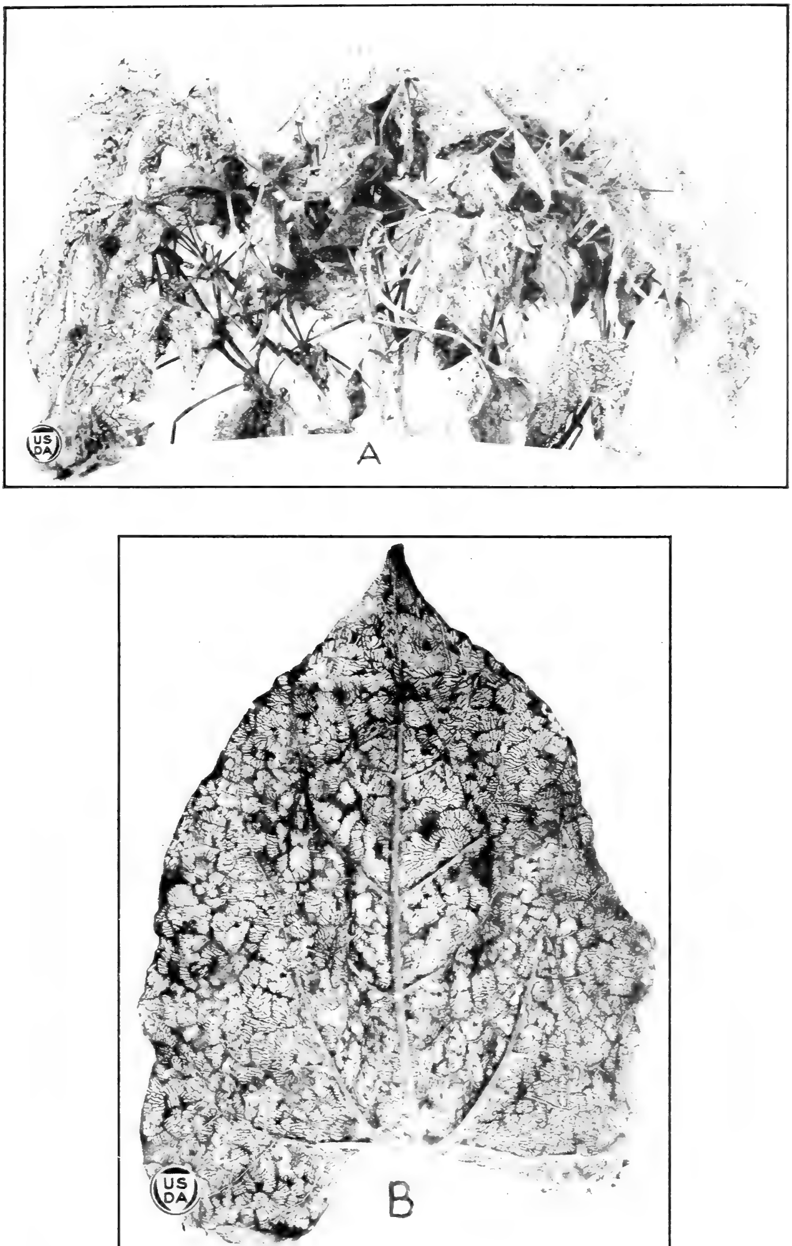
	Eggs.		Eggs.		Eggs.
Sept. 5[2]	..	Sept. 20	64	Oct. 9	55
9	62	23	63	24	47
11	60	26	55	Nov. 8	58
14	64	30	68		
17	54	Oct. 3	58	Total	708

No. LH-3G3: Female emerged August 31; 15 days between emergence and first eggs.

	Eggs.		Eggs.		Eggs.
Sept. 15	62	Oct. 3	63	Nov. 13	67
19	30	9	63		
24	61	24	60	Total	524
27	65	Nov. 2	53		

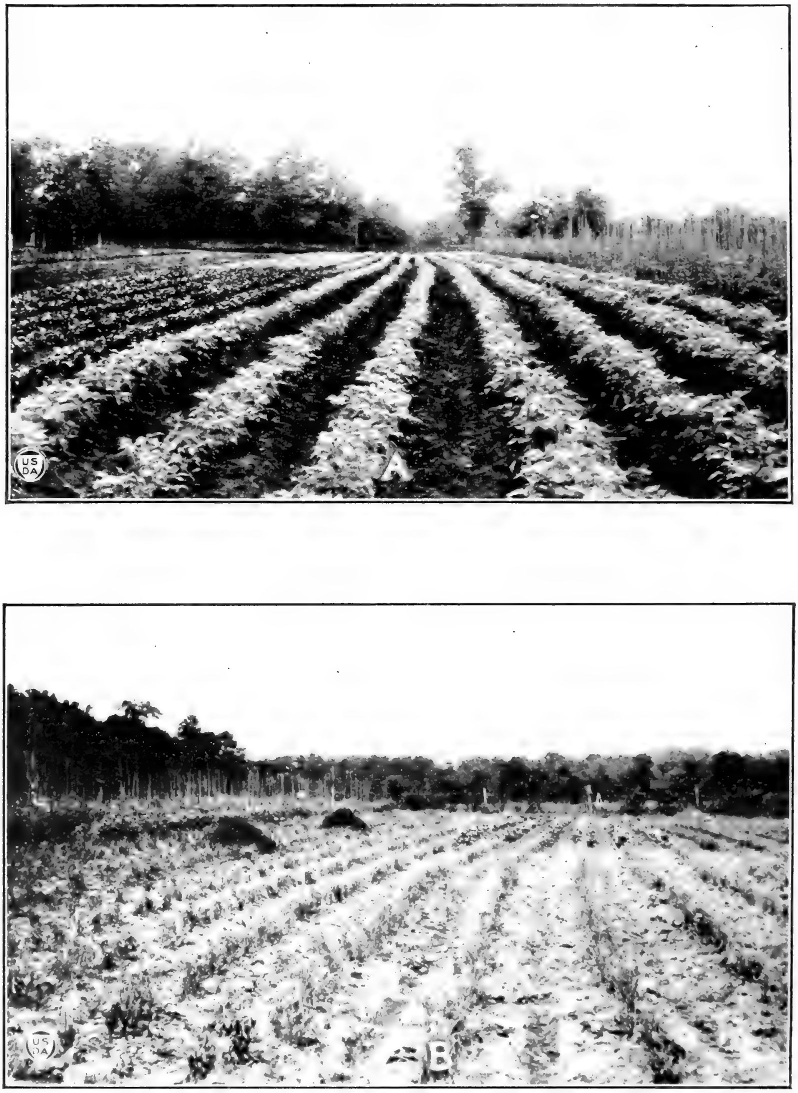
[2] Mating observed this date. Females paired when emerged except in case of LH-9 and LH4-2, 1921, which were isolated.

The average number of eggs laid by all the females for which records are complete for the two seasons is shown in Table 2.



LARVAL FEEDING OF THE MEXICAN BEAN BEETLE

A, Bush bean plant destroyed by larvæ; *B*, bean leaf showing characteristic feeding



DESTRUCTION OF BEANS CAUSED BY THE MEXICAN BEAN BEETLE

A, Beans destroyed by Mexican bean beetle (note contrast with younger beans not destroyed, to the left); *B*, same field as shown in *A* after rain and wind had beaten leaves from plants

TABLE 2.—*Eggs laid by 69 females of the Mexican bean beetle for which records are complete, 1921 and 1922.*

Generation.	1921		1922	
	Number of females.	Average number of eggs per female.	Number of females.	Average number of eggs per female.
Overwintered generation	10	507	15	252
First generation	4	708	11	286
Second generation	5	1, 272	8	479
Third generation	12	413	4	422
Average for 69 females (two seasons)				459

Some females laid no eggs and others only one or two groups, but these are included in the above averages. The average for all females as given is probably low, for in nature some of the overwintered females may have deposited eggs the preceding fall, and some of the third and fourth generation females, and a very small number of the second generation, might have deposited eggs the ensuing spring.

Of 15,804 eggs laid in cage tests in 1921, 46.7 per cent hatched. Of 7,024 eggs deposited in 1922, 52.5 per cent hatched. The lower percentage in 1921 was due in part to the very low percentage of eggs hatching which were laid during the high temperature of August.

The Mexican bean beetle is polygamous. A single fertilization of the female is sufficient for the production of as many as 10 groups of fertile eggs, even though five months or more passed in hibernation intervene between mating and the first egg deposition in the spring. (See Table 1.) Gravid females may thus enter hibernation and without further intervention of the male deposit fertile eggs in the spring. The beetles always feed on foliage in the spring before oviposition.

The young larvæ hatch from the eggs after from 5 to 14 days, depending upon temperature conditions, the average incubation period at Birmingham, Ala., during June, July, and August being 6 days. Hatching of all eggs in a group usually occurs within 24 hours. The newly hatched larvæ leave the eggshells and cling to the tips of the eggs, completely covering the shells. They begin to feed soon after leaving the eggs, many of them reaching the leaf and feeding while clinging to the eggshells about the edge of the group. A very thin layer of epidermis is eaten. After a day or so the larvæ begin to scatter and feed more heavily, devouring thicker portions of the leaf. By the time of the first molt they have scattered over several leaves. As they grow older they feed heavily and more rapidly and scatter over the plant or adjacent plants. In the third and fourth larval instars the most serious damage is done to the crop.

The larvæ (Pl. IV, *C*) remain on the plant on which they have hatched, or on adjacent plants. While capable of crawling a considerable distance under adverse conditions, as much as 24 feet in 20 minutes, migrations do not usually occur except prior to pupation when sufficient protection is not at hand.

The larva's method of feeding is characteristic of the species. (Pl. V, *A*, *B*.) It consumes a narrow band of the leaf and usually leaves the upper epidermis intact. It then moves and consumes another strip, and so on until several such parallel strips have been

devoured. The result is a network of narrow bands of leaf tissue covered by the thin upper epidermis. The feeding habits of the beetle are quite similar to those of the larva in many cases, but usually the leaves are more ragged in appearance.

The 12-spotted cucumber beetle (*Diabrotica 12-punctata* Oliv.) feeds very similarly in many cases, as do also certain small caterpillars.

In territory where the bean beetle is not numerous, specimens of suspected insects should be taken for identification before the presence of the bean beetle is reported.

After the larva has molted three times the fourth larval instar or stage appears. Feeding by the larva in this stage is very destructive, a single larva being able to destroy a large bean leaf in one day. After feeding for from 4 to 6 days in moderately warm weather the larva attaches itself by means of an abdominal pad at the posterior end and remains quiescent for about 2 days. A fourth larval molt then occurs and the pupa stage is assumed. The larval skin, which is white in color, remains attached to the yellow-colored pupa (Pl. II, *B;* Pl. III; Pl. IV, *D*), covering the posterior abdominal segments and holding the pupa to the leaf or other object. Late in the fall the pupal skin is often black in streaks and sometimes completely black. Under conditions of severe infestation, pupæ occur on various plants and objects near destroyed plants. Egg masses are also deposited on such plants as mustard, cocklebur, and certain weeds, on which the hatching larvæ would starve.

The adult or beetle emerges from the pupa in from 6 to 8 days. Immediately on emergence it is light lemon-colored and very soft. In a few hours the spots on the wing covers appear. The wings are protruded backward from under the elytra or wing covers, extending a distance almost the length of the body. At the end of 24 hours the adult becomes fully developed and quite hard, but the color is light lemon, with black spots, and dark mouth parts, undersurfaces, and appendages. With age the color becomes darker, approaching copper color to brown in overwintered specimens.

Newly emerged adults (Pl. IV, *E*) usually remain on the bean plant and feed before taking flight. Food is not essential, however, and in cases where fields are destroyed newly emerged beetles fly away in search of food.

The fecundity of the insect under favorable circumstances is remarkable. During the summer of 1921 many fields of beans about Birmingham, Ala., were so heavily infested that the general appearance of the crop resembled the effect of a severe drought. Scattered over the remains of the plants, the ground, weeds, and any object were thousands of pupæ and larvæ, so numerous as to give a yellow tone to the field. Larvæ and beetles feed on pods and stems under such conditions.

The total life period from egg to adult covers from 25 days during the heat of summer to 58 days in early spring, the usual minimum being 27 days during summer, and the usual maximum during the spring and fall being about 44 days. From 6 to 29 days additional are required between emergence of the female from the pupa and egg deposition. The average preoviposition period for 32 females in two different seasons was 11.5 days. Table 3 gives a brief summary of the life history at Birmingham, Ala., for the years 1921 and 1922.

TABLE 3.—*Summary of life history of the Mexican bean beetle at Birmingham, Ala., 1921 and 1922.*

[Average days of development.]

1921: 2,019 EGG-TO-ADULT RECORDS.

Generation.	Incubation period.	First instar.	Second instar.	Third instar.	Fourth instar.	Pupation period.	Developmental period.
	Days.	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*
First generation	10	5	6	4	8	6	39
Second generation	6	4	3	3	6	6	28
Third generation	6	4	3	3	6	6	28
Fourth generation	6	3	3	4	8	7	31
1922: 1,407 EGG-TO-ADULT RECORDS.							
First generation	8	5	4	5	8	6	36
Second generation	6	4	4	4	8	7	33
Third generation	6	4	4	4	8	7	33
Fourth generation	7	5	5	7	10	12	46

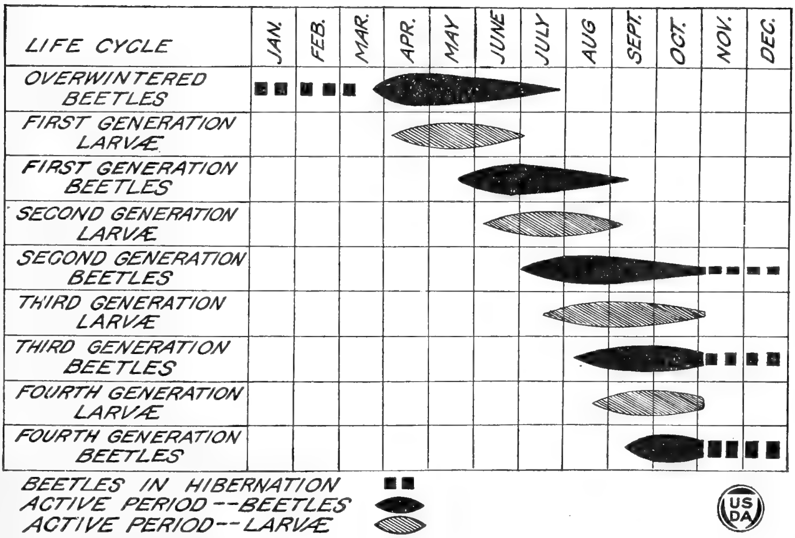


FIG. 6.—Life history of the Mexican bean beetle in an open-air insectary and field cages at Birmingham, Ala., during 1921. Based on 2,393 egg-to-adult rearings.

SEASONAL LIFE HISTORY.

The discussions in this bulletin are based on observations covering only a two-year period in a restricted locality, which is too short a time to draw conclusions on many phases, especially since this study deals with an insect in a new habitat with a constantly increasing distribution.

A large series of life-history experiments were performed during the two seasons, 1921 and 1922, and these have been condensed into charts. (Figs. 6, 7.) Figure 6 gives the results of 2,393 egg-to-adult rearings, obtained during the year 1921, chiefly by J. R. Douglass. Figure 7 gives the results of 1,590 egg-to-adult rearings, obtained

during 1922 by L. W. Brannon. During 1922 many egg masses obtained were not reared. All the original beetles were taken from hibernation. Cages were placed in the field as well as in the insectary, and identical results were obtained.

These charts show overlapping of generations, due to the prolonged life of the adults, especially the overwintering generation. They also show that while the insect can and does produce a maximum of four generations, a minimum of two is required to maintain the species except in rare instances. Two generations and a partial third are the rule.

All stages of the insect occur in the field from late April or early May until late October or early November about Birmingham, Ala. At Thomasville, Ga., all stages have been observed in the field from April until late November or even December. A maximum of four

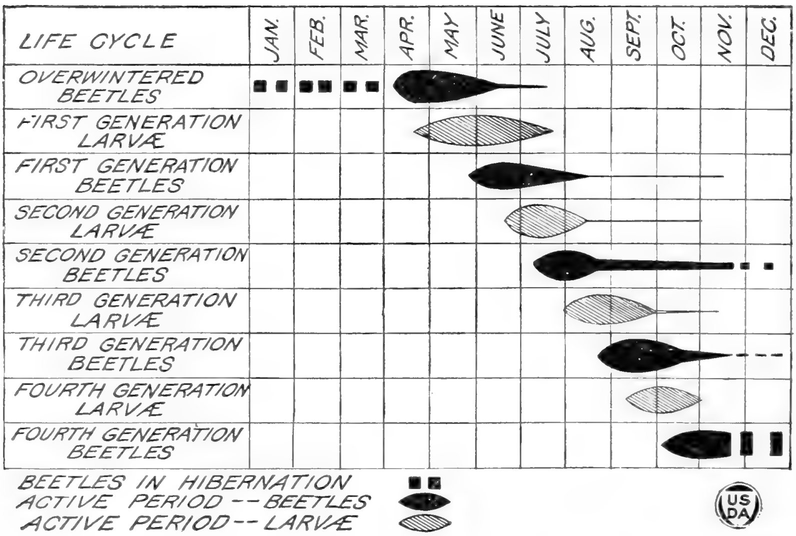


FIG. 7.—Life history of the Mexican bean beetle in an open-air insectary and field cages at Birmingham, Ala., during 1922. Based on 1,590 egg-to-adult rearings.

generations occurred there, although the duration of bean plantings would permit a maximum of six generations. Two generations and a partial third are the rule, as in northern Alabama.

In the field the severest damage is done by the first and second generations.

Figure 8 represents the seasonal life history. This chart was prepared from the life-history studies and records of infestation made in field control experiments during 1921 and 1922. The width of the bands indicates the relative abundance of the beetles and larvæ, calculated from injury to beans. The early records of 1921 are probably unusual, and the heavy late infestations of that year were not repeated in 1922. The heaviest infestation occurs in July and early August, when the greatest number of larvæ are present. In 1921 the period of heavy infestation extended over a period of about three months from late June to the middle of September, but in 1922 this period was of shorter duration—from late June to early August.

In the Southeast the beetles begin to leave their winter quarters in the spring as early as late March and early April, or at about the time when early garden beans are coming up. At Birmingham, Ala., this date was March 22 in 1921, and April 6 in 1922. At Chattanooga, Tenn., it was early in May in 1922. At Thomasville, Ga., the first beetles emerged in the field March 27, 1922. One individual of a colony of beetles, marked black, November 18, 1921 (Group 2, Table 6), was collected in a bean field April 22, 1922, three-fourths of a mile from the place where it had spent the winter. The beetle is thus able

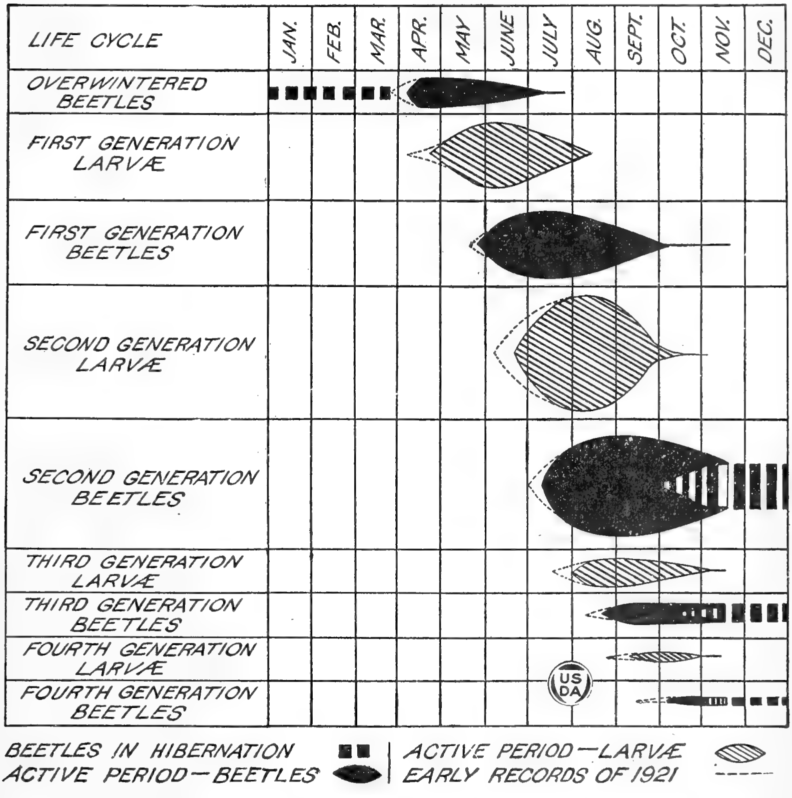


FIG. 8.—Seasonal life history of the Mexican bean beetle: Composite chart prepared from insectary records and field observations during 1921 and 1922 near Birmingham, Ala. (eggs and pupæ not shown). Width of bands shows relative abundance of beetles and larvæ in the field. The insect is most abundant in July.

to make extensive flights at this time of the year. In New Mexico, J. E. Graf found beetles hibernating $7\frac{1}{2}$ miles from the nearest bean field, and still farther from the most likely source.

The spring migration lasts until early June, covering a period of about two months. The beetle flies considerably all during the summer from field to field and travels great distances.

During August, 1921, and late July, 1922, the beetles became restless and were often on the wing. During this period beetles a week or more old fed less than earlier in the season. It is believed that the greatest distribution occurs during the late summer and early fall, but the spring migration is also undoubtedly of great importance.

At least as early as the first week in October the beetles begin to fly to woodlands and enter hibernation. The majority have left the fields by the time the daily mean temperatures reach 55° to 60° F., but a few remain until heavy frosts occur.

Fewer eggs are laid after the middle of August. Larvæ are correspondingly scarce, but all stages are present until killing frosts occur.

Life for long periods without food, as shown by starvation tests, indicates that the species is remarkably prepared for adverse conditions when host plants may be unavailable. One adult lived 102 days without food in the presence of moisture. In general they

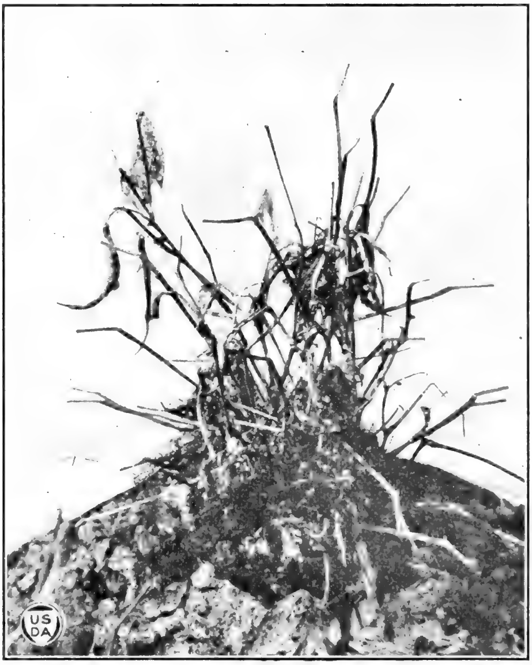


FIG. 9.—A typical infested bean plant photographed in the field shown in Plate VI, *B*.

succumb to starvation after 5 to 15 days, but a few live considerably longer. After starving for 68 days, 19 beetles out of 50 survived and entered hibernation November 22, 1922. An adult with food lived 121 days. The average life of 34 pairs used in experiments was 58 days, the females averaging 50 days and the males 68.

FOOD PLANTS.

The Mexican bean beetle is primarily a bean pest (Pl. VI, *A*, *B;* text fig. 9), attacking by preference the common beans, including bush and pole varieties of snap beans, pinto, navy, and Lima beans, and tepary beans, all of the genus Phaseolus. It can subsist, however, on a number of other plants, and in many instances has severely damaged cowpeas and soy beans. About Birmingham, Ala., in 1921, and about Chattanooga, Tenn., in 1922, some fields of cowpeas were

destroyed, and serious injury in some instances was done to soy beans. The following list of food plants comprises those observed to date, in the order of their preference, on which both larvæ and beetles can subsist, as observed in the field.

FOOD PLANTS OF THE MEXICAN BEAN BEETLE.

Tepary bean (*Phaseolus acutifolius*).
Garden bean (*Phaseolus vulgaris*); including navy bean, pinto bean, kidney bean, pole bean, etc.
Lima bean (*Phaseolus lunatus*).
Beggarweed (*Meibomia tortuosa, M. canescens, M. viridiflora*).
Hyacinth bean (*Dolichos lablab*).
Cowpea and black-eyed pea (*Vigna sinensis*).
Soy bean (*Glycine hispida*).
Adsuki bean (*Phaseolus angularis*).
Alfalfa (*Medicago sativa*).
Sweet clover (*Melilotus alba*).

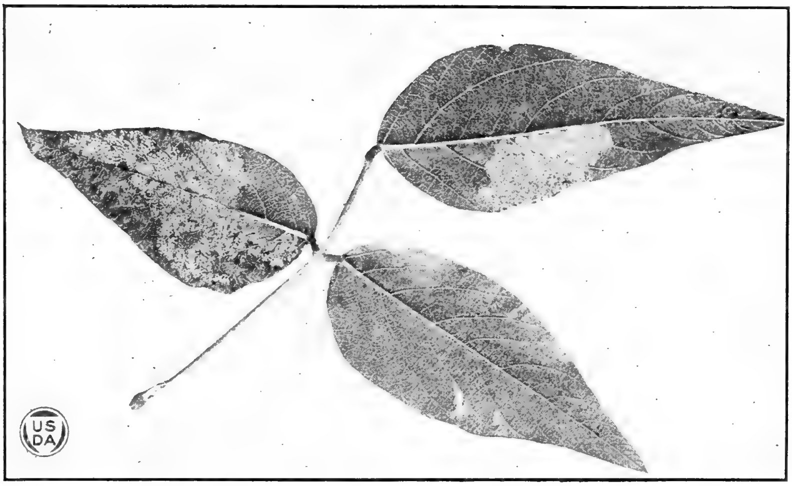


FIG. 10.—Voluntary larval feeding on beggarweed (*Meibomia* sp.).

There is a very great difference in choice between some of these food plants. In some cases of light infestations, cowpeas and soy beans may be uninjured. Also, early in the season, beetles and larvæ may starve in confinement on these plants, while later in the year they will reproduce on them and may cause serious injury in the field in cases of heavy infestations.

In the late summer and fall, when bush bean foliage is scarce but when pole Lima beans are large and green, the beetles are attracted to the latter. This crop is examined closely in fall scouting work in new territory. The list given is based on field observations.

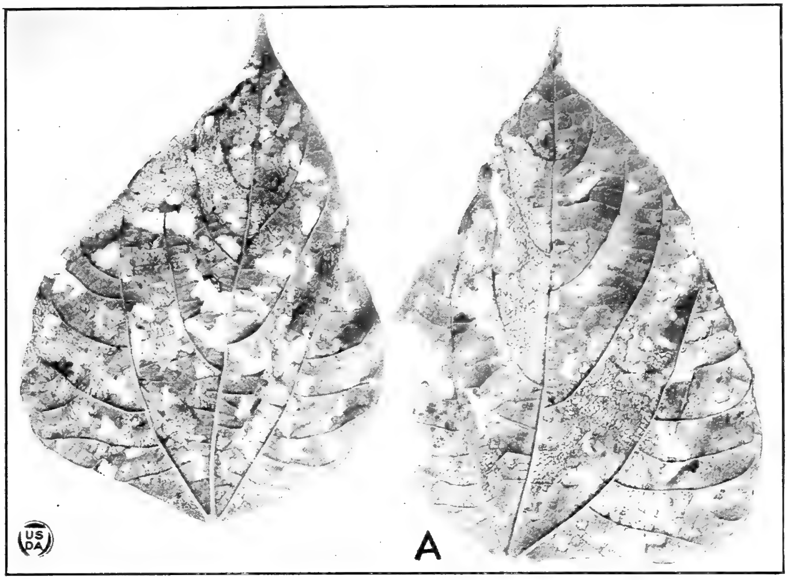
In the insectary the insect has been reared from egg to adult on many varieties of bean—on *Meibomia canescens* (fig. 10), cowpea (Pl. VII, *A*, *B*), hyacinth bean, soy bean (Pl. VIII, *B*), and adsuki bean—and to the pupa stage on alfalfa, when ants destroyed the pupæ. The likelihood of the insect severely damaging plantings of the adsuki bean, sweet clover, or alfalfa (Pl IX, *A*) is very remote. Beetles and larvæ in confinement often starve in the presence of the last two plants. When extremely numerous the beetles have been

observed to feed voluntarily on many plants, especially when their favorite food has been destroyed or has become scarce. Among these plants are the following: Velvet bean, kudzu, crimson clover, white clover (Pl. IX, *B*), corn, grasses, okra (Pl. VIII, *A*), eggplant, potato, squash, mung bean (*Phaseolus aureus*), and weeds. None of these plants has ever been severely damaged. Adults have also been taken feeding on *Galactia volubilis* and *Lespedeza virginica*. In the fall volunteer feeding on kudzu is not uncommon, while trials earlier in the year to breed the insect on this host have been fruitless. Feeding on mung bean (*Phaseolus aureus*) is very rare, and only one instance of feeding on wild morning-glory (*Ipomoea* sp.) has been observed, under unusual conditions. The insect does not normally feed on sweet potato or peanut. Information relative to the preference of the beetle for snap beans, both pole and bush, compared with Lima beans, cowpeas, and soy beans, may be gained from the reports on field scouting, most of which was done in sections where infestation was light. These reports show a decided preference of the beetle for the garden bean over the Lima bean, that the cowpea is far removed from either of these, and that the latter is preferred to soy bean. In south Georgia beggarweed (*Meibomia tortuosa*) is preferred to cowpea, this plant being infested with all stages of the insect when cowpea is scarcely infested.

The problem of food plants of the Mexican bean beetle is not the same in the Southeast as in the West and Southwest. Not only does the problem concern the grower of susceptible crops, but it has an important bearing on the policy to be followed regarding quarantine and extermination policies. The fact that a number of new food plants came under observation immediately after investigation of the problem is evidently explained by the fact that the insect acts differently under new climatic conditions. Obviously, also, some apparently new habits may be of old standing.

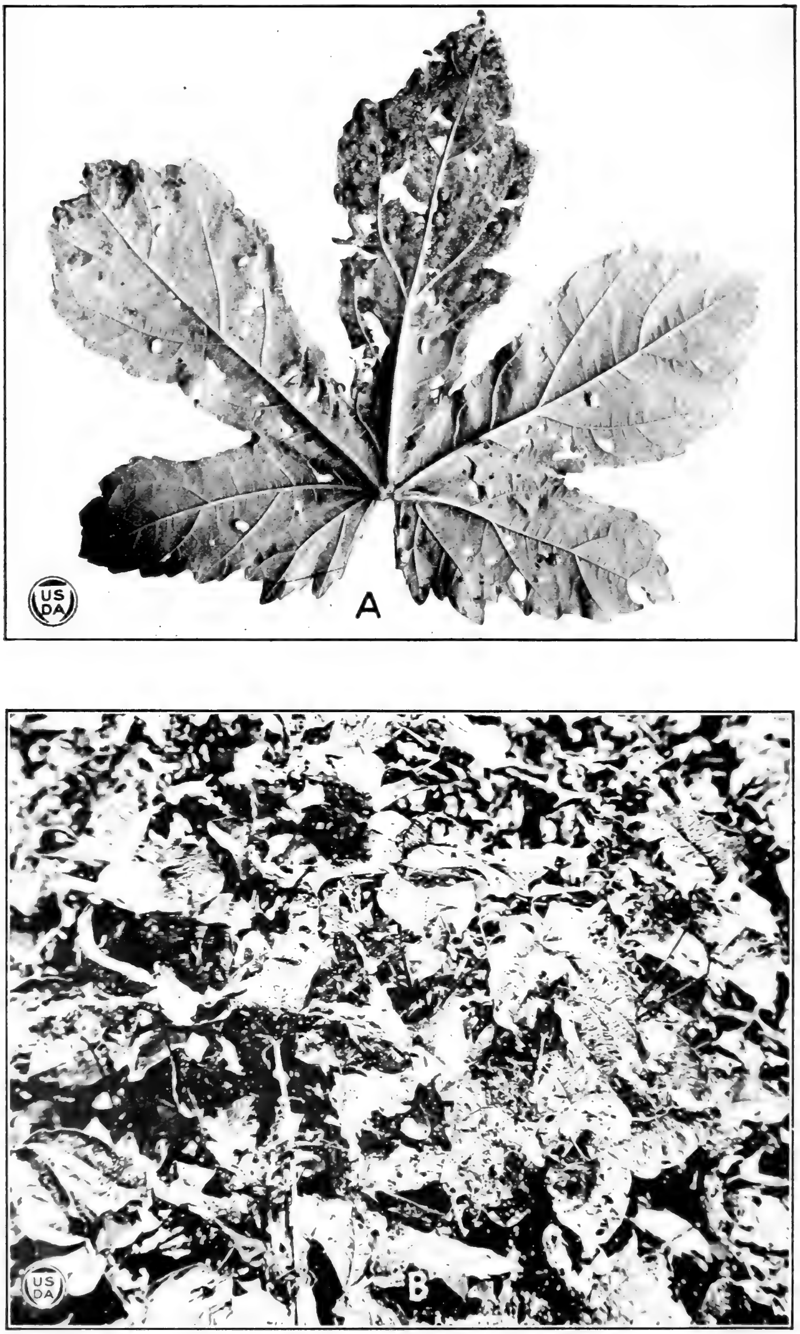
Soon after the avidity of the beetle for beggarweed or beggartick (*Meibomia tortuosa*) in southern Georgia was reported by Luther Brown, the same facts were independently discovered in Mexico by Prof. H. F. Wickham, while employed by the Bureau of Entomology. Similar observations were made in northern Alabama by J. R. Douglass and the writers and subsequently in Mexico in 1922 by E. G. Smyth. It is therefore probable that Meibomia has been a host plant for many years. In 1920, when the bean beetle was first reported in northern Alabama, cowpea and soy bean were observed as food plants. Adults were first observed feeding on soy bean, in Colorado, by A. E. Mallory, Bureau of Entomology, in 1919. The greater variety and accessibility of leguminous food plants in the southeastern part of the United States, together with the abnormal abundance of the insect, has probably been the chief cause of changes of habit and new observations of old habits. In trucking sections in the Southeast cowpeas are often raised as a truck crop for human consumption in the green stage. In many such instances severe damage has been done to this crop. In a number of cases marked injury to fields of cowpea of considerable size has occurred, but always in a section where the infestation on garden beans has been extremely heavy.

A decided preference is shown by the Mexican bean beetle for "pinto" and tepary beans. In 1921 pinto, or Rosello spotted, beans



WORK OF THE MEXICAN BEAN BEETLE ON COWPEA

A, Voluntary larval and adult feeding on cowpea; *B*, beetles feeding on cowpea leaf



WORK OF THE MEXICAN BEAN BEETLE ON OKRA AND SOYBEAN

A, Okra leaf, taken in field, showing beetles and larvæ feeding; *B*, soybeans injured by feeding

from Colorado were planted with a legume collection on the experimental plats. Careful counts showed that more than twice as many adults were present on the pinto beans, and they were destroyed sooner than a collection of six of the most popular varieties of garden bush beans. In 1922 tepary beans were decidedly preferred to 11 varieties of the commonest pole and bush beans, although the leaves were small and the insect was exposed to the sun. These facts support the statement that the bean beetle was introduced from the western part of the United States, for these varieties are grown extensively there.

HIBERNATION.

Knowledge of the hibernation habits of the Mexican bean beetle previous to the winter of 1921–22 was based on the collection of very few specimens during the fall and winter. The greater portion of the life cycle of many important injurious insects, especially in the Temperate Zones, is passed in a dormant state during winter, but in many instances little is known about this stage. Attack on insects during this period has been found successful in notable cases, such as the clean-up practices recommended in some localities against the chinch bug, *Blissus leucopterus* Say, and the planting of wheat to take advantage of the seasonal life history and hibernation habits of the Hessian fly. Other outstanding examples might be mentioned.

The adult of the bean beetle is the only stage which survives the winter. In 1921 emergence from hibernation was first noted March 22, when four adults were collected on early beans. An egg mass was also collected, indicating that emergence had occurred a few days before. In field observations emergence and spring migration lasted until the middle of May, the greatest number having emerged by late April and early May.

Restlessness of adults in the field was noted in August, 1921, and from that time until late October migrations occurred. Beetles were exceedingly numerous until that time, but had almost disappeared from the field by November 4, when a heavy frost occurred. A few specimens were observed up to November 25, 1921, on parts of bean foliage which had not been killed by frost.

Adults of the Mexican bean beetle have been found hibernating under various conditions. They have been collected in old stumps near a garden, in cracks of old fence posts, in débris about an old fence, in stone piles near a garden, under leaves and plant remains in the garden, under a woodpile, and in well-drained woodlands near bean fields.

Experience gained in California in investigating the hibernation of beneficial coccinellids led J. E. Graf to believe that the Mexican bean beetle, which is a coccinellid, hibernates similarly. Therefore, a large area surrounding the Birmingham trucking district in the East Lake section was carefully searched for the beetle during the winter of 1921–22. The results are given in Table 4.[4]

This area comprised approximately 12 square miles and the same territory was searched again in the winter of 1922–23. These results are shown in Table 5.

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[4] M. P. Foshee, D. M. Dowdell, Jr., and others assisted in this work.

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TABLE 4.—*Hibernation of the Mexican bean beetle, Birmingham, Ala., winter of 1921–22.*

Hill No.	Number of searches.	Number of square feet covered.	Number of colonies found.	Number of beetles found in colonies.	Number of single beetles found.	Total number of beetles found.
1	10	515	0	0	3	3
2	20	1,023	3	649	154	803
3	25	1,686	0	0	63	63
4	3	344	1	30	32	62
5	4	374	0	0	3	3
6	3	196	0	0	1	1
7	17	420	0	0	0	0
8	5	1,896	0	0	43	43
9	42	7,989	4	233	287	520
10	7	690	0	0	0	0
11	7	1,075	0	0	1	1
12	12	629	0	0	26	26
13	27	2,287	0	0	34	34
14	12	882	0	0	0	0
15	5	500	0	0	38	38
16	19	644	0	0	2	2
18	6	488	0	0	0	0
19	8	991	0	0	0	0
20	9	1,113	0	0	0	0
21	10	1,750	0	0	267	267
22	6	968	0	0	2	2
23	11	936	0	0	3	3
24	11	1,152	0	0	0	0
25	6	376	4	380	2	382
26	8	339	0	0	0	0
27	5	480	0	0	0	0
28	7	360	0	0	4	4
29	5	603	0	0	1	1
30	5	35	0	0	0	0
31	13	1,433	0	0	11	11
32	13	476	0	0	0	0
38	13	478	0	0	0	0
39	13	390	0	0	12	12
40	12	364	0	0	0	0
41	9	361	0	0	0	0
42	7	291	0	0	0	0
43	7	580	0	0	0	0
44	7	559	0	0	0	0
45, Watt's farm	62	5,086	0	0	9	9
Total	471	40,759	12	1,292	998	2,290

TABLE 5.—*Hibernation of the Mexican bean beetle, Birmingham, Ala., winter of 1922–23.*

Hill No.	Number of searches.	Number of square feet covered.	Number of colonies found.	Number of beetles found in colonies.	Number of single beetles found.	Total number of beetles found.
1	13	554	0	0	1	1
2	20	1,276	0	0	1	1
3	59	4,933	0	0	10	10
4	46	3,449	0	0	17	17
5	15	522	0	0	0	0
6	45	4,334	0	0	0	0
7	15	557	0	0	0	0
8	27	1,958	0	0	0	0
9	77	7,484	0	0	14	14
11	21	1,042	0	0	0	0
12	38	4,168	3	167	145	312
13	15	829	0	0	0	0
15	27	2,609	0	0	3	3
16	7	299	0	0	0	0
19	23	1,167	0	0	2	2
21	36	3,139	0	0	31	31
22	39	3,660	0	0	0	0
23	37	1,998	0	0	0	0
25	39	1,580	0	0	54	54
26	23	1,082	0	0	0	0
28	13	484	0	0	0	0
32	30	1,526	0	0	4	4
45	56	5,244	0	0	0	0
Total	721	53,894	3	167	282	449

Approximately 12 square miles were included in hibernation scouting. The greatest distance beetles were found from a bean planting is one-half mile. The majority of the beetles found were within one-eighth to one-fourth mile from the nearest bean plantings.

The largest numbers of hibernating beetles have been found in woodlands where the land is rolling. In all cases where living beetles were taken, the material sheltering them was moist and was protected from driving winds. As this material dried out, during warm weather, the beetles moved about and went farther into the material where moisture was present, or migrated to more favorable quarters.

In sections where the infestation is extremely heavy there is a tendency toward hibernating gregariously. About Birmingham, Ala., in the winter of 1921–22, 56 per cent of the 2,290 beetles observed were found in colonies. The following winter, 1922–23, only 14.8 per cent as many beetles were found per unit of area as during the previous winter. This was probably due to the lighter infestation during 1922.

The largest colony observed contained 329 beetles on December 15, 1921, and the majority of beetles occurred in a space 18 inches square. The colony shown in Plate X, *A*, *B*, contained 149 beetles, more than 50 of which were in a space less than 1 foot square, about 1 inch below the surface. This colony was under pine needles and oak leaves which had accumulated under a pine branch on the ground.

During cold weather in January adults withstood submersion in water for two days with no mortality. Fifty per cent of the beetles survived after submersion for four days, and one beetle was living after six days. In small hibernation cages which were not sufficiently moist all beetles succumbed.

Males and females occur in approximately equal proportions.

The few beetles which remain in the bean fields during winter are undoubtedly a factor in the spring infestation, but the large majority of adults migrate from the fields to wooded hills. The proper moisture conditions for successful survival of the winter appear to be an important factor in determining the location chosen. These conditions are only constant under branches and leaves in the shade, or in deep piles of material. The preferred material in the Southeast is a mixture of pine needles and oak leaves. (Pl. X.) The beetles are found distributed through the material at a depth of an inch or more, depending on the moisture conditions. Adults are occasionally found with colonies of the beneficial ladybird, *Megilla maculata* DeG.

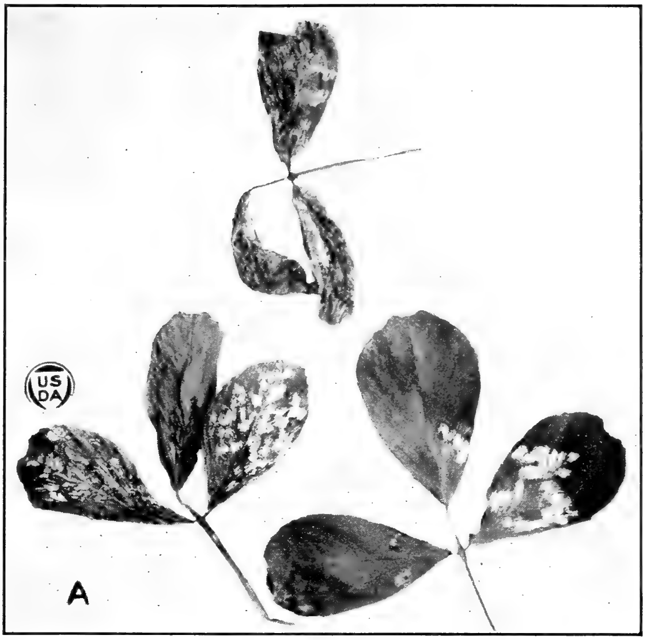
October 3, 1922, three beetles were observed in hibernation in woodlands when the shade temperature was 82° F. Three days later 25 beetles were found in the same place.

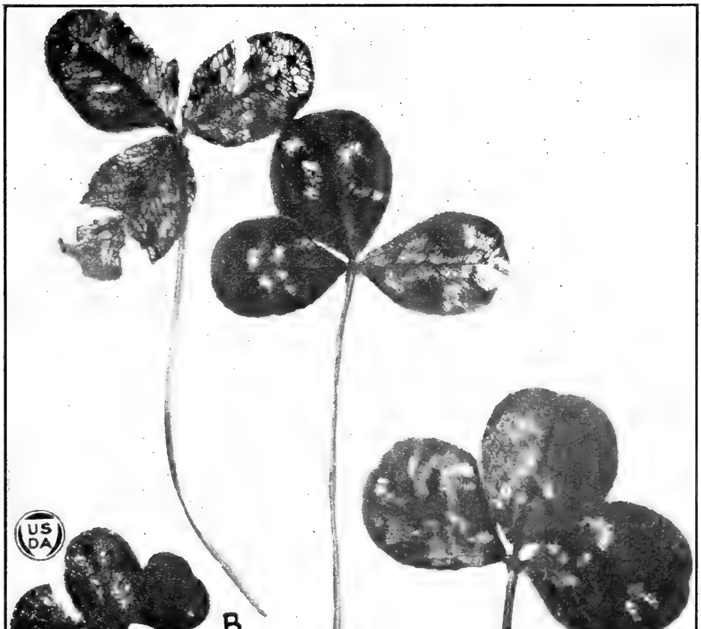
During the mild winters of the Southeastern States the adults are not entirely inactive. On warm days they move about, and in the course of the winter the majority change location. Some of the colonies of beetles found in woodlands were watched throughout the winter. Each beetle was marked with a waterproof mark. Brief records of the observations are given in Tables 6 and 7.

TABLE 6.—*Data on colonies of Mexican bean beetles in hibernation, winter of 1921–22.*

Date.	Number of painted beetles.	Number of unpainted beetles.	Dead beetles.	
			Painted.	Unpainted.
GROUP 1.				
[149 beetles in original colony, marked red, November 22, 1921.]				
1921.				
Nov. 30		24		
Dec. 9		47		
Dec. 15	Destroyed by intruders.			
GROUP 2.				
[299 beetles in original colony, marked black, November 18, 1921.]				
1921.				
Nov. 30		30		
Dec. 9	200	103		
Dec. 15	161	168	6	2
1922.				
Jan. 3 [1]	156	170	6	9
Jan. 17	156	166	10	14
Jan. 22	116	141	11	10
Feb. 17	93	115	5	29
Feb. 24	85	110	95	9
Mar. 8	65	85	7	7
Mar. 18	54	54	3	6
Mar. 29	40	38	4	2
Apr. 13	25	18	1	0
Apr. 26	10	8	0	0
May 10	0	0	0	0
GROUP 3.				
[80 beetles in original colony, marked purple, December 10, 1921.]				
1921.				
Dec. 15	68	8		
1922.				
Jan. 3	59	11	3	0
Jan. 17	47	9	1	1
Jan. 31	57	9	0	1
Feb. 18	51	9	0	1
Feb. 23	41	8	1	1
Mar. 6	37	6	1	1
Mar. 18	30	6	0	1
Mar. 27	24	4	1	0
Jan. 6	Beetles noted with snow on ground; more closely grouped.			
Feb. 23	Temperature moderating and beetles scattered generally through covering.			
Apr. 13	16	1	0	0
Apr. 26	5	1	0	0
May 10	0	0	0	0
GROUP 4.				
[65 beetles in original colony, marked white on left wing cover, December 10, 1921.]				
1921.				
Dec. 15	43	12		
1922.				
Jan. 3	40	10	1	1
Jan. 17	35	16	0	0
Jan. 31	29	8	0	2
Feb. 18	26	11	0	0
Feb. 23	22	13	0	0
Mar. 6	20	5	0	7
Mar. 18	20	3	1	0
Mar. 27	13	5	0	0
Apr. 13	9	4	0	0
Apr. 26	3	1	1	0
May 10	0	1	0	0

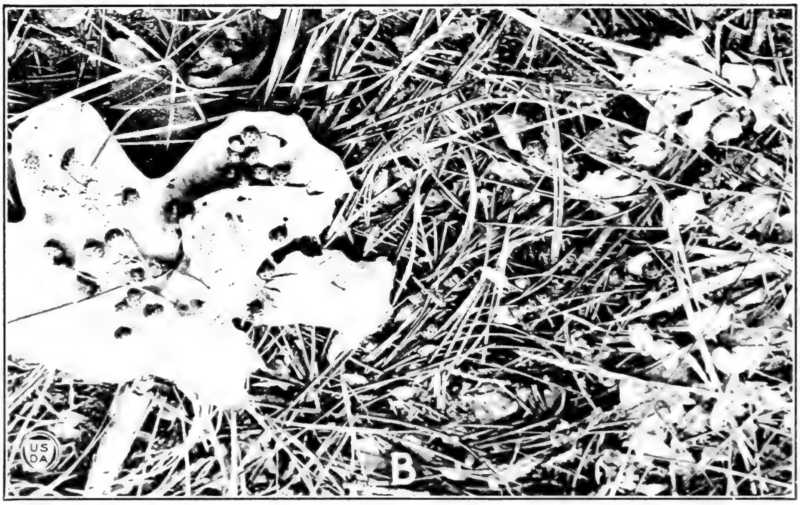
[1] Majority of beetles found in space 18 inches square.





WORK OF MEXICAN BEAN BEETLE ON ALFALFA AND CLOVER

A, Voluntary feeding on alfalfa; *B*, voluntary feeding on white clover



HIBERNATION OF THE MEXICAN BEAN BEETLE

A, Woods in which Mexican bean beetle was found hibernating in colonies; *B*, Mexican bean beetles hibernating gregariously in woods under pine straw and oak leaves. *B* was taken after pine branch shown in foreground in *A* was removed

TABLE 6.—*Data on colonies of Mexican bean beetles in hibernation, winter of 1921–22*—Continued.

GROUP 5.

[72 beetles in original colony, marked green on right wing cover, December 13, 1921.]

Date.	Number of painted beetles.	Number of unpainted beetles.	Dead beetles.	
			Painted.	Unpainted.
1921.				
Dec. 15	70	0	....	....
1922.				
Jan. 3	Destroyed by intruders.		....	....

GROUP 6.

[103 beetles in original colony, marked red (eosin) on right wing cover, December 13, 1921.]

Date.	Number of painted beetles.	Number of unpainted beetles.	Dead beetles, painted.	Dead beetles, unpainted.
1921.				
Dec. 15	96	0	....	....
1922.				
Jan. 3	85	4	3	0
Jan. 17	69	1	4	0
Jan. 22	68	2	4	0
Feb. 18	65	0	0	0
Feb. 23	64	0	0	0
Mar. 7	57	3	0	0
Mar. 18	51	1	0	0
Mar. 27	40	3	1	0
Apr. 13	18	1	0	1
Apr. 26	3	1	0	1
May 10	0	0	0	0

TABLE 7.—*Data on colonies of Mexican bean beetles in hibernation, winter of 1922–23 (through Feb. 9, 1923).*

GROUP 7.

[25 beetles in original colony, in space 3 feet by 5 feet, Oct. 3, 1922.]

Date.	Number of beetles present.
1922.	
Nov. 6	8
Nov. 8	3
Nov. 10	4
Nov. 12	4
Nov. 21	4

GROUP 8.

[61 beetles in original colony, in space 4 feet square, Dec. 4, 1922.]

Date.	Number of beetles present.
1922.	
Dec. 14	16
Dec. 20	0

TABLE 7.—*Data on colonies of Mexican bean beetles in hibernation, winter of 1922–23 (through Feb. 9, 1923)*—Continued.

GROUP 9.

[81 beetles in original colony, in space 5 feet by 10 feet, marked black, Dec. 20, 1922.

Date.	Number of beetles painted.	Number of beetles unpainted.	Remarks.
1922.			
Dec. 20	81		
Dec. 30	31	15	Slightly active.
1923.			
Jan. 5	30	19	Inactive.
Jan. 12	29	19	Slightly active.
Jan. 31	21	12	Active.
Feb. 9	22	21	Inactive.

The mortality in the woods during hibernation is not as great as might be expected. Remains of beetles have been found which indicate the work of carabid beetles or other predacious enemies. The high mortality in Group 2 (Table 6) is unusual.

Records of hibernation were also obtained from cages. At Birmingham, Ala., 17,800 beetles were placed in cage 1, and were given their choice of materials which had been found by Dr. W. E. Hinds to be satisfactory the previous winter. The materials used were wood, sticks, cornstalks, and bean vine débris, a fourth of the cage being left bare. The cage was placed under a small tree which shaded it about half the day. Beetles numbering 18,050 were placed in cage 2, similar to cage 1, and with similar materials, but in a location a mile and a half away, where the cage was not shaded. These cages were placed at an altitude of about 600 feet above sea level, in latitude 33° 31′ N.

Observations were made of cage 2 at intervals during the winter. As noted in the field observations, many of the beetles moved about on warm days throughout the winter.

Air temperatures were taken in the shade as observations were made. No beetles were observed to be out of the hibernating material below a temperature of 50° F., and very few were out at temperatures below 60° F. At 60° F. and above, up to 70° F., from 30 to 200 beetles would crawl about the top of the material and on the sides of the cage, depending on the amount of sunlight. Above 70° F., the beetles became more active, and March 30, 1922, at 75° F., 724 beetles were out and active. Early spring migration and issuance from hibernation probably took place under natural conditions about that date, although the first adult was not taken on beans until April 6. After March 20 the beetles in the cages were active at temperatures below 60° F. on some days. April 1, when the temperature was 45° F., 124 beetles were out. Almost all the beetles hibernated under the pile of wood and sticks, several inches below the surface, where the material was constantly moist. A few beetles hibernated in the bean vine débris.

In the spring, about the time appearance on the earliest garden beans was expected, as indicated by observations of beetles under natural conditions, beetles were removed as fast as they crawled on the sides of the cage. The emergence in the cages is given in Table

8. It will be noted that the survival of beetles was slightly less than 15 per cent in each cage.

The total period of emergence was about two months—from April 5 to June 6. The maximum emergence occurred between April 19 and May 6 in the two cages, which is more than a week later than the previous year. The majority of the beetles observed throughout the winter in nature (Table 6) had left hibernation by April 26, and all except one had issued by May 10.

TABLE 8.—*Hibernation at Birmingham, Ala., winter of 1921–22.*

CAGE 1.

Beetles collected.		Beetles removed.	
Date.	Number.	Date.	Number.
Sept. 21	500	Apr. 5	100
Sept. 22	800	Apr. 12	85
Sept. 23	6,000	Apr. 22	220
Sept. 24	5,200	Apr. 27	180
Sept. 29	600	May 3	300
Sept. 30	4,700	May 5	753
		May 6	301
		May 8	267
		May 12	102
		May 19	203
		June 2	73
		June 6	16
Total	17,800	Total	2,600
		Percentage survival	14.61

CAGE 2.

Beetles collected.		Beetles removed.	
Date.	Number.	Date.	Number.
Oct. 1	4,700	Apr. 4	100
Oct. 2	1,350	Apr. 5	314
Oct. 3	3,000	Apr. 12	186
Oct. 5	3,200	Apr. 17	1,036
Oct. 7	1,800	Apr. 19	213
Oct. 8	4,000	May 4	453
		May 8	231
		May 20	105
Total	18,050	Total	2,638
		Percentage survival	14.61

HIBERNATION AT CHATTANOOGA, TENN.

The Mexican bean beetle reached Chattanooga, Tenn., early in 1921, and reproduced rapidly that year. It had not become abundant, however, by fall. In October, 18,000 beetles, collected at Birmingham, Ala., were placed in hibernation on Lookout Mountain in Tennessee, in a cage and with materials for protection similar to those used at Birmingham, Ala. The altitude of this mountain is more than 2,100 feet above sea level, and the latitude is 35° 21′ N. Beetles were removed when the locality was visited and the results are given in Table 9. The survival in this cage was lower than in the others, probably because the beetles were not removed regularly. No attempt was made to estimate the mortality due to starvation in the spring, but it is believed that a higher percentage of survival would have been obtained if the cage had been observed daily. Of the adults placed in this cage, 9.7 per cent survived the winter. The

maximum emergence, estimated from observations, probably occurred from May 10 to May 27, which is three weeks later than at Birmingham, Ala., where cages were placed at 600 feet above sea level, at 33° 31′ N. latitude. The insect at the latitude and altitude of Lookout Mountain remains in hibernation from 7½ to 8 months.

TABLE 9.—*Data on hibernation cage at Chattanooga, Tenn., on Lookout Mountain, winter of 1921–22.*

Beetles collected at Birmingham, Ala.		Beetles emerged.	
Date.	Number.	Date.	Number.
Oct. 5	6,000	Apr. 26	37
Oct. 6	12,000	May 16	465
		May 18	585
		May 27	629
		June 10	24
Total	18,000	Total	1,740
Beetles transported to Chattanooga and placed in cage Oct. 11.		Next observation was June 29, when there were no living beetles in the cage.	
		Percentage survival	9.7

HIBERNATION AT THOMASVILLE, GA.

The isolated infestation at Thomasville, Ga., offers an interesting comparison of the habits of the Mexican bean beetle at a low altitude (about 300 feet above sea level) and more southern latitude (30° 54′ N.) with those at the higher altitudes and more northern latitudes of Birmingham, Ala., and Lookout Mountain, Tenn.

Hibernating habits under natural conditions at Thomasville, Ga., during the winter of 1921–22 were very similar to those about Birmingham, Ala. Because of the lighter infestation and the relatively smaller acreage of bean plantings, adults were not so numerous. An area of several square miles surrounding the city was included in the study of hibernation. A total area of 4,823 square feet, representing 718 searches, was examined carefully. Of 152 adults observed in hibernation, 69 per cent were found in a colony comprising 105 beetles. These were found at the base of a large oak, growing in contact with a large gum tree. The beetles were distributed from 1 to 3 inches below the surface in oak and gum leaves. Close by was a garden which had contained pole Lima beans which had been destroyed by the beetle the previous summer.

In searching for hibernating bean beetles many adults of the related squash beetle[5] were also observed in hibernation, often under identical conditions, side by side, under leaves on the ground. The well-known habit of the squash beetle of hibernating in crevices in the bark of trees has not been observed in the case of the bean beetle.

A hibernation cage like those mentioned above was used at Thomasville. (See Table 10.) In 1921 the majority of the beetles left the fields late in October, but a few were present as late as December. The first issuance from hibernation observed in the field was March 29, 1922, but, as noted in Table 10, emergence began February 28 in the cage and continued until June 3. The survival was 30

[5] *Epilachna borealis* Fab.

per cent. This high rate, however, may be partially due to the fact that the dormant period of a portion of the beetles is reduced to less than four months.

TABLE 10.—*Data on hibernation cage at Thomasville, Ga., winter of 1921–22.*

Beetles collected.		Beetles issued.	
Date.	Number.	Date.	Number.
1921.		1922.	
Sept. 28–30	1,690	Feb. 28	79
Oct. 1–6	1,625	Mar. 1–11	153
Oct. 8–15	708	Mar. 13–18	97
Oct. 17–25	259	Mar. 27–31	93
Oct. 26–31	234	Apr. 1	116
Nov. 1–10	342	Apr. 2	30
Nov. 12–18	253	Apr. 3–6	339
Nov. 25–30	190	Apr. 7–12	154
Dec. 1–12	157	Apr. 13–19	261
		Apr. 21–28	170
1922.		May 1–6	90
Jan. 21	24	May 8–13	43
Jan. 31	12	May 17	27
		May 22	3
		May 26	2
		May 29	6
		June 3	1
Total	5,494	Total	1,667
		Percentage survival	30.34

HIBERNATION CAGE SUMMARY.

Cage.	Number of beetles placed in cage.	Number of beetles emerged.	Per cent survived.
Thomasville, Ga.	5,494	1,667	30.3
Birmingham, Ala., Cage 1	17,800	2,600	14.6
Birmingham, Ala., Cage 2	18,050	2,638	14.6
Chattanooga, Tenn. (Lookout Mountain)	18,000	1,740	9.7

The maximum emergence in the cage occurred between April 1 and April 6, when 485 emerged, which is 18 to 31 days earlier than at Birmingham, Ala., and 39 to 51 days earlier than at Chattanooga, Tenn.

In the mild climate of southern Georgia the time between the earliest entrance into hibernation and the latest emergence covers about 7 months, a relatively long period. The time from the entrance of the last beetle into hibernation until the first emergence is only about 3½ months. The majority of the beetles remain in hibernation about 5 months. These habits may change, however, as the insect becomes adapted to that climate, which is entirely different from the conditions prevailing in the Southwestern States, where the species has thrived for three-fourths of a century.

NATURAL CONTROL.

The known natural enemies of the Mexican bean beetle are relatively few in the Southeastern States. None has been of much economic importance since the insect reached that section, and it

will no doubt require many years for native enemies to become adapted to it. No insect or other enemy has been observed to effect any appreciable control in the western part of the United States.

PREDACIOUS ENEMIES.

The following predacious insect enemies have been observed to prey on the Mexican bean beetle, *Epilachna corrupta*, in the field, and most of these have been observed in confinement.

The common coccinellid beetle, *Megilla maculata* DeG., was very abundant about Birmingham, Ala., during the summer of 1921. This beneficial species fed, in both the larval and adult stages, on the eggs of the bean beetle, and occasionally on young larvæ. Many egg masses were attacked and a few eggs of each destroyed. The bean beetle was so abundant that less than 3 per cent of the eggs were destroyed. During 1922 Megilla was not abundant, and very few eggs were destroyed.

The convergent lady-beetle *Hippodamia convergens* Guér., also eats the eggs of the bean beetle, but sparingly. The adults of *Coccinella sanguinea* L. and *C. novemnotata* Hbst. feed slightly on the eggs, the latter species more generally on younger larvæ. *Adalia bipunctata* L. feeds slightly on the eggs and small larvæ.

A common soldier-bug, *Stiretrus anchorago* Fab., destroys larvæ, pupæ, and beetles. It is not common until late in the season, and then is not sufficiently abundant to be of much value. This bug, both in the last nymphal and in the adult stages, is at present the most effective native enemy.

Another pentatomid bug, *Podisus maculiventris* Say, feeds in both nymphal and adult stages on larvæ, pupæ, and adults of the bean beetle and is a more active feeder than Stiretrus. It is not generally as numerous as Stiretrus, and is therefore less effective. Both of these bugs can subsist for long periods on a bean beetle diet.

The common wheel-bug, *Arilus cristatus* L., feeds on larvæ, pupæ, and beetles, but is too rare to be effective.

The ground beetles might be expected to prey on the bean beetle, especially when the latter is so abundant as to destroy a field of beans and the larvæ crawl about in search of food. No beneficial effects have been observed from this source, though three native species, *Harpalus caliginosus* Fab., *Scarites subterraneus* Fab., and *Calosoma sayi* Dej., eat larvæ sparingly, and the latter two species attack pupæ and beetles in confinement.

The tiger beetles *Tetracha carolina* L., and *T. virginica* L., both larvæ and adults, feed voraciously in confinement on larvæ, pupæ, and adults of the bean beetle and occur in infested fields. It is not certain that they feed voluntarily on this insect in nature, and their habits would not indicate that they are very important enemies. They are not present in numbers in well-cultivated fields.

The larvæ and adults of the lace-wing flies *Chrysopa oculata* Say and *C. rufilabris* Burm. feed on pupæ of the bean beetle. They are not numerous and are of little importance.

In the fall of 1921 a number of instances of feeding by caterpillars on pupæ of the bean beetle were noted. In three instances the larvæ matured in confinement on a diet of bean-beetle pupæ and developed into normal moths, two of which were identified by Dr. F. H. Chittenden as *Prodenia ornithogalli* Guen., and the third as *Laphygma*

frugiperda S. & A. A fourth collected in the field proved to be *Heliothis obsoleta* Fab. (Pl. XI, *C*.) These unusual habits may have been caused by the destruction by the bean beetle of the bean foliage on which these insects had been feeding.

The ants *Solenopsis geminata* Fab. and *Pheidole* sp. destroyed bean-beetle pupæ in experimental cages during the summer of 1921.

The adult of *Epilachna corrupta* has been observed to feed on its own eggs in the field in the presence of green bean foliage, and larvæ have also been observed feeding on pupæ in the presence of other food, but very rarely. In the absence of green foliage, adults and larvæ very commonly feed on pupæ and eggs of the bean beetle, but not to a sufficient extent to be important in natural control.

Not infrequently dead larvæ and pupæ, light brown to dark brown in color, are observed in the field, attached to leaves. Bacteriological examinations of such specimens by Dr. G. F. White showed the presence of unidentified Coccobacillus and Streptococcus. Attempts to inoculate healthy larvæ by spraying cultures, furnished by Doctor White, on bean plants exposed to the larvæ availed nothing. It appears, however, that in the field during the summer a low percentage of larvæ and pupæ succumb to a bacterial disease.

PARASITES.

The Mexican bean beetle has been exceptionally free from parasites in the United States. No internal insect parasites have been recorded heretofore, and none was observed during the season of 1921. In 1922, however, a few native parasites of native insects were reared from the bean beetle.

Phorocera claripennis Macq. (Pl. XI, *A*) was common during July and early August, and a considerable number were reared from egg to adult in cages on third and fourth instar larvæ of the bean beetle during that period, but the species gradually became scarce and disappeared from the field by September 1. The female fly deposits distinct white eggs on the larva. (Pl. XI, *B*.) Only one larva of the parasite completes its development in the host. This species, although the most common native parasite during 1922, did not become abundant enough at any time to effect any appreciable natural control. It has many other hosts.

The sarcophagid fly *Helicobia helicis* Towns.[6] was reared in two instances from bean-beetle larvæ. This general feeder is also rare.

In 1921 Prof. H. F. Wickham collected a puparium of a parasitic tachinid fly in the vicinity of Mexico City, Mexico. In 1922 E. G. Smyth, later in the season, collected numbers of these puparia and shipped them to Birmingham, Ala. The fly occurs very late in the season, but is reported to parasitize 30 to 50 per cent of the larvæ of *Epilachna corrupta* in Mexico. It has been recently described by Dr. J. M. Aldrich as *Paradexodes epilachnae*.[7] More than 300 were successfully reared in the insectary at Birmingham on third and fourth instar larvæ of the bean beetle, and a few were liberated. A considerable number of puparia, also, were held in hibernation. Emergence continued during mild weather in the winter, when the

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[6] Determined by Dr. J. M. Aldrich, of the U. S. National Museum.

[7] Proceedings of the Entomological Society of Washington, vol. 25, No. 4, April, 1923, pp. 95–96.

host was hibernating as an adult, and this habit may make colonization difficult. This parasite appears to be capable of immense benefit.

Phytophagous Coccinellidae in Java, according to Dr. P. van der Goot, entomologist to the Dutch Government, are attacked in the egg, larva, and pupa stages by Hymenoptera; hence it appears that other parasites that may prove useful against *Epilachna corrupta* may be found.

EFFECT OF SUNLIGHT.

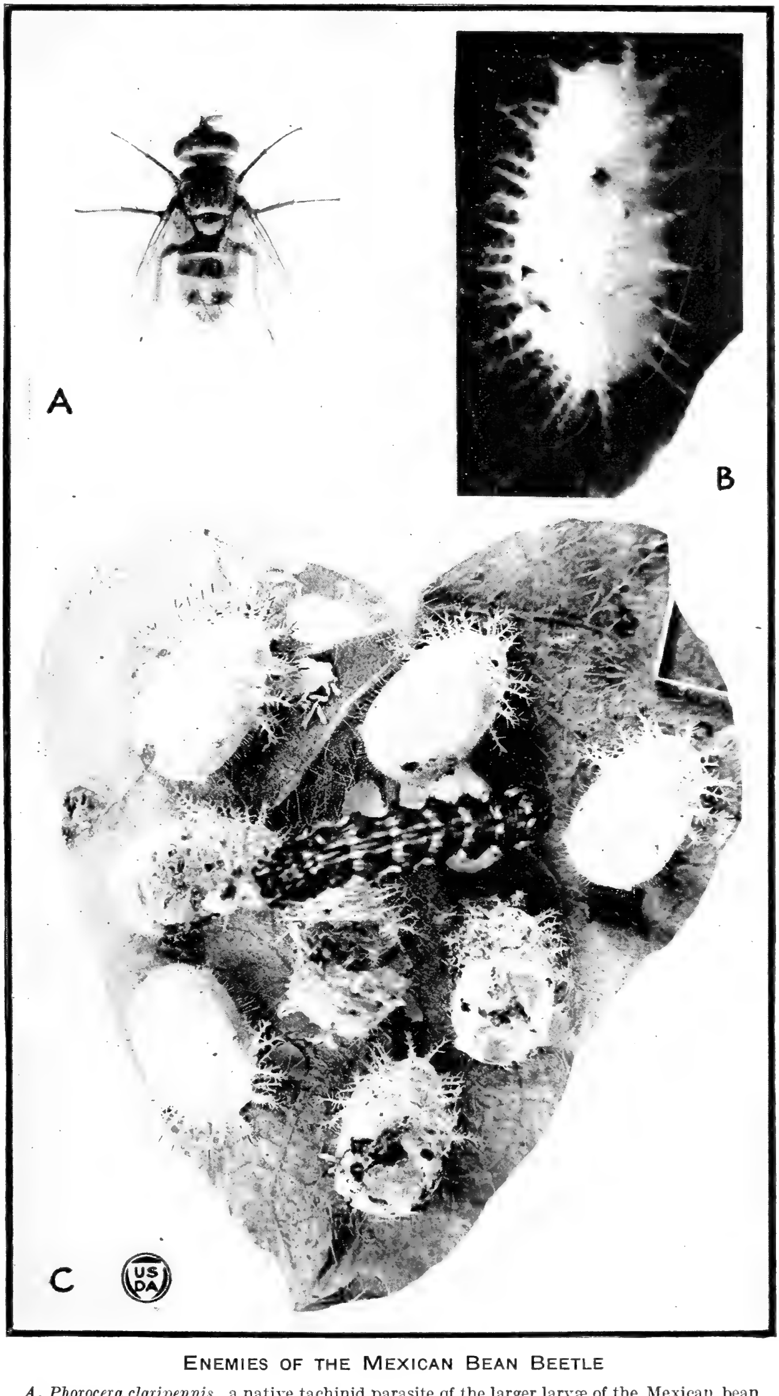
During a prolonged hot dry period in 1921, when bean beetles were so numerous that they destroyed all bean plantings in the Birmingham district, the larvæ were forced to crawl about in search of food, and were also exposed to the sun on the stems and stalks of plants. Pupæ were so numerous that many stalks and pods were literally covered with them, and many larvæ pupated on the ground, or on stones, weeds, or any object at hand. Many thousands of pupæ gradually turned brown and died.

Experiments were performed and various stages of the insect were exposed to sunlight. The eggs, which are normally protected from direct sunlight, are occasionally laid on the upper surface of the leaf, or, when laid on the under surface, may be exposed in some instances by bean leaves growing upward. This is often the case with the tepary bean. An exposure to sunlight for 33 hours on four consecutive days in June killed 57 eggs when the shade temperature ranged from 74° to 94° F., but 15 eggs of a group of 59 hatched after 30 hours' exposure on the same days. Twenty-four groups, totaling 1,240 eggs, exposed to the sun continuously from three to five days during late July and August at shade temperatures reaching a maximum of from 80° to 101° F., succumbed with the exception of two eggs.

An exposure to direct sunlight for two minutes was fatal to first-instar larvæ 1 day old when shade temperatures registered 96° F. Second-instar larvæ, 5 days old, succumbed after seven minutes' exposure to direct sunlight when the shade temperature registered 92° F. Third-instar and fourth-instar larvæ succumbed after 10 minutes' exposure to direct sunlight when the shade temperature registered 93° F.

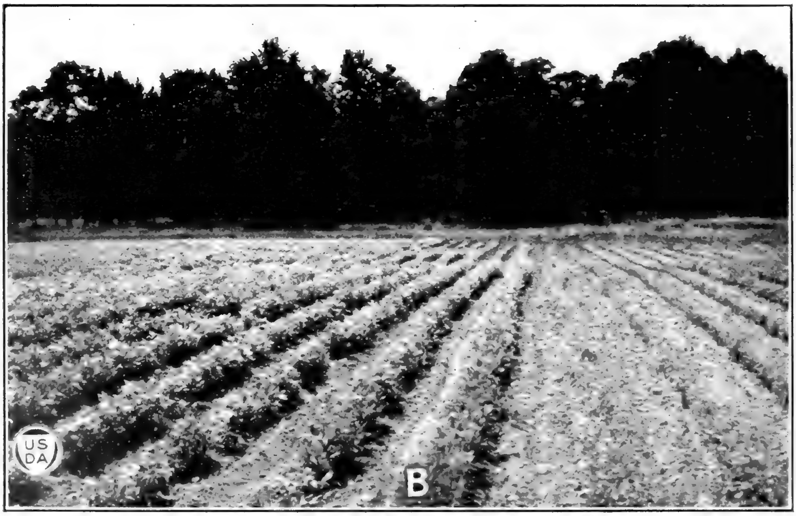
Three hundred pupæ were collected in the field September 12 and exposed to the sun for two days when maximum shade temperatures each day registered 96° F., and all succumbed, while 78 per cent of a check of 100 pupæ emerged in the shade, and all pupæ reared in the shade in other experiments emerged. Undoubtedly most of the 22 per cent of pupæ of the check lot had been killed by sunlight in the field.

Adults are more resistant, and since they can fly to sheltered places are not usually killed by effect of sunlight. Under conditions of light or medium infestation, large numbers of the various stages of the insect are not exposed and no great benefit from this source occurs. All in all, however, the factors enumerated above, and no doubt others which were not observed, tended to reduce the number of adults going into hibernation to such an extent that the infestation was much lighter in 1922 than in 1921.



ENEMIES OF THE MEXICAN BEAN BEETLE

A, Phorocera claripennis, a native tachinid parasite of the larger larvæ of the Mexican bean beetle, × 2½; *B,* eggs of *Phorocera claripennis* on fourth-stage larva, × 6; *C,* corn earworm feeding on pupa of Mexican bean beetle, × 4



BENEFICIAL EFFECT OF SPRAYING FOR THE MEXICAN BEAN BEETLE

A, Untreated check plats of beans destroyed by Mexican bean beetle alongside of plats treated with magnesium arsenate, used as a spray; *B*, same plats as shown in *A*, one week later, after leaves had dropped; sprayed beans to the left

GENERAL METHODS OF CONTROL.

Reduction of the infestation by cleaning up hibernation quarters offers an excellent method of control. In sections where waste lands are sought by the beetle, cleaning up can best be accomplished during the fall or spring by burning. Fence rows and inaccessible portions can be burned effectively by means of a blowtorch designed for the purpose, along the lines of a cactus or pear burner, such as is used in the Southwest for burning spines from prickly pear. It has been discovered that the beetle seeks places somewhat sheltered and where accumulations of leaves, pine needles, or plant débris occur. In such instances the material may be gathered in piles and burned, with especial care to prevent the spread of the fire over woodlands.

Burning can not usually be recommended for the Southeast because of the loss which would result in many sections where woodlands are abundant and are of economic value. Loss of timber, game, and beneficial insects in many cases would exceed the benefit gained, since the value of the bean crop would not equal the loss. Also, the beetle is capable of long flights to hibernation, and the area to be burned would be greater than with many other species of insects. In more densely populated sections, or in sections where the major part of the land is tilled, and where waste places are necessarily sought by the beetle, this practice will undoubtedly be very beneficial. Where woodlands are relatively small, burning of the materials which shelter the beetles may be practiced without detriment to the timber. This practice would require a close community effort over a considerable area, and would be promising only in cases where the area suitable for hibernation is restricted.

Under conditions of severe infestation, fields which are badly injured should be plowed under before the larvæ develop into beetles.

Covering any stage of the beetle with 1 inch or more of clay soil during hot weather destroys it.

The growing of beans under conditions of heavy infestation is impossible without the use of remedial measures. Only as many beans as can be treated should be planted. The expense of treating pole beans, on account of the difficulty of application and the longer period to maturity, which involves more applications, makes it advisable to grow only bush beans where infestation is heavy.

Where green beans are grown, the infested fields should be plowed as soon as the crop is picked. This will destroy large numbers of all stages of the bean beetle and will reduce the infestation. Community effort is essential in this practice, and will benefit each grower.

For the winter months fields should be planted to cover crops best suited to conditions.[8] This will add organic matter to the soil and stimulate a vigorous growth and early maturity the following year, thus tending to compensate for bean beetle injury.

Plant varieties which do not produce large, bushy foliage. Too leafy a foliage can not be as thoroughly covered by arsenicals as varieties which produce less foliage.

Plant seed in the drill. Clumps of plants are more difficult to reach with insecticides than row crops.

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[8] Farmers' Bulletin 1250, entitled "Green Manuring."

ARTIFICIAL CONTROL.

At the outset the problem of artificial control of the Mexican bean beetle appeared to be a matter of the application of the proper stomach poison to the bean foliage. Some experience had been gained along these lines by State and bureau workers in the West and Southwest. The general conclusion from these investigations was that lead arsenate and zinc arsenite are the most satisfactory arsenicals for the control of the Mexican bean beetle, these being recommended as sprays.

INVESTIGATIONS OF 1921.

ARSENICALS.

The work for 1921 was therefore planned with a view to learning what results could be obtained in the Southeastern States by these sprays. A number of other arsenicals were also tried, chiefly calcium arsenate and magnesium arsenate. A large series of experiments was conducted with various dilutions of all of these arsenicals, both as sprays and as dusts. After completing the first experiments, it appeared as though lead arsenate and zinc arsenite were promising materials, since check plats were totally destroyed and excellent protection was afforded treated plats. Experiments were continued, however, and it was soon learned that the plant injury caused by these arsenicals makes them hardly worthy of recommendation to the grower, on account of reduced yields.

Different factors were found to influence this plant injury. Attention was called by Dr. William Moore, formerly of the Bureau of Entomology, and C. M. Smith, Insecticide and Fungicide Laboratory, Bureau of Chemistry, to the effect on lead arsenate of the water available in the Birmingham district. Further experiments were performed, and it was learned that lead arsenate is absolutely unsafe for application to bean foliage, even with distilled water, or diluted with hydrated lime and used as a dust. It was also learned that zinc arsenite causes a serious reduction in yield, even though the injury to the plant is not as noticeable as injury caused by lead arsenate. Experiments proved that calcium arsenate is absolutely unsafe for bean foliage without the application of an excess of lime along with the material. These results were also obtained when the materials were used as dusts.

Throughout all the experiments magnesium arsenate, a commercial preparation which has not been generally used on account of the injury to foliage of different kinds of fruit trees, was found to be safe on bean foliage, even though used with the water of the district, which is relatively high in soluble sodium salts. Under conditions of severe infestation in 1921 unsatisfactory results were obtained with dilutions of those arsenicals which were injurious to foliage in the undiluted state.

Since magnesium arsenate is not generally available to bean growers, and because of the fact that growers in the Southern States were more familiar with dusting methods than with spraying methods, a tentative recommendation was made that calcium arsenate of a high grade be diluted with 9 parts of hydrated lime and be applied to the foliage as a dust. The amount of arsenic in this mixture,

however, was so low that entirely satisfactory results were not obtained under conditions of severe infestation. Magnesium arsenate was therefore recommended because it was the only arsenical known which could be used without dilution and not cause plant injury.

OTHER INSECTICIDES.

Experiments were also conducted with materials other than arsenicals. Nicotine dusts were thoroughly tried. Various strengths of dust were used, ranging from 0.38 per cent nicotine content to 4 per cent nicotine content. The insecticidal properties of these dusts against the Mexican bean beetle were nil.

A number of experiments were performed with pyrethrum powder, used undiluted as a dust and combined with various diluents, such as cornstarch and hydrated lime. Decoctions of pyrethrum powder were also used. It was found that pyrethrum powder and certain decoctions thereof were very toxic to the adult of the Mexican bean beetle, less toxic to the larvæ, and almost ineffective against the eggs and pupæ. Because of the high cost of the material, however, and the frequent applications required, pyrethrum is absolutely impracticable for field control.

A number of new compounds were tried in an experimental way in cooperation with Dr. William Moore and C. M. Smith. While some of these materials may be of value, not one of them has as yet warranted recommendation over some of the better known available arsenicals.

INVESTIGATIONS OF 1922.

The problem presented in the 1922 experiments in artificial control was the use of an arsenical which would not be injurious to bean foliage and at the same time would be sufficiently toxic to the Mexican bean beetle to insure satisfactory control, the former requirements being the more limiting.

Since magnesium arsenate and calcium arsenate with an excess of lime were the most promising arsenicals tested in 1921, these, as well as basic lead arsenate, were used on a larger scale than others.

A few experiments were performed with lead arsenate and zinc arsenite in order to check the results obtained the previous season. A number of other compounds were also the subject of experiment.

SPRAYING AND DUSTING MACHINERY USED IN EXPERIMENTS.

The power sprayer (figs. 11, 12) referred to is a 150-gallon capacity, triplex-pump, high-pressure potato sprayer, equipped with a high-speed 5-horsepower engine, and was used in experiments as a 4-row sprayer, 3 nozzles per row, at 250 pounds pressure.

An arrangement was improvised to permit the driver to raise and lower the boom with one foot when turning around or driving over uneven places.

The wheelbarrow sprayer (fig. 13) is a 15-gallon capacity, hand-operated outfit, capable of maintaining 150 pounds pressure at two nozzles. It was mounted on a narrow slide and pulled by one horse. Two men were required—one to pump and one to spray. The arrangement of the nozzles on a U-shaped pipe attached to the spray rod made it possible to spray a row at the speed the horse walked.

The hand sprayer (fig. 14) referred to is a 3-gallon capacity, compressed-air type, which it is estimated produces from 40 to 65 pounds pressure if pumped at intervals of 100 feet of row.

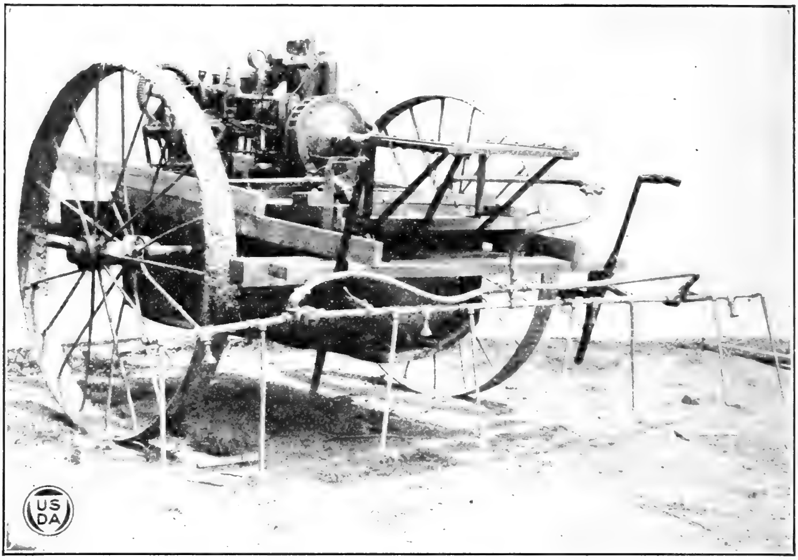

FIG. 11.—Power sprayer used in experiments against the Mexican bean beetle, showing arrangement of nozzles and device for raising the boom.

The knapsack type of hand bellows duster used is illustrated in Figure 15. The power duster used is shown in Figure 16.

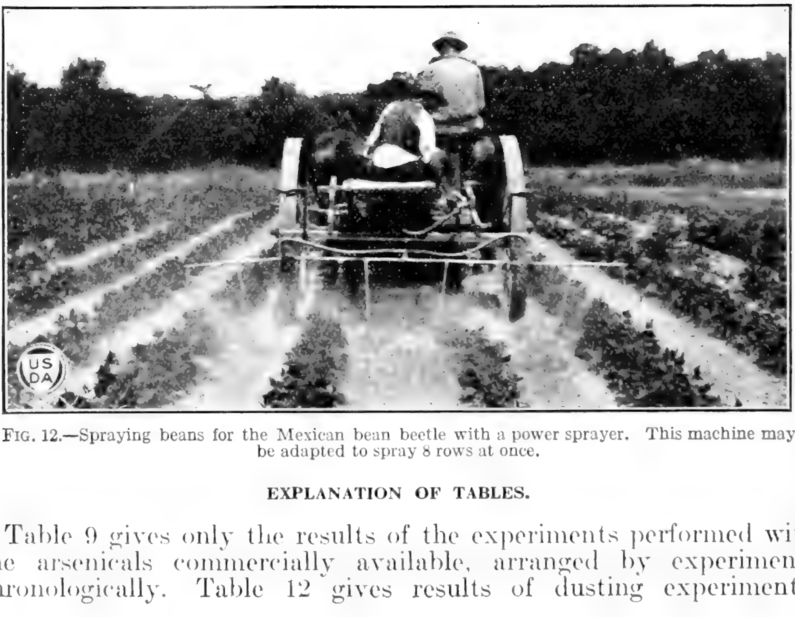

FIG. 12.—Spraying beans for the Mexican bean beetle with a power sprayer. This machine may be adapted to spray 8 rows at once.

EXPLANATION OF TABLES.

Table 9 gives only the results of the experiments performed with the arsenicals commercially available, arranged by experiments chronologically. Table 12 gives results of dusting experiments,

arranged by insecticides. Table 13 gives results of spray experiments arranged by insecticides. The infestation was not as severe as in 1921, and comparisons between experiments must take into consideration the degree of infestation.

FIG. 13.—Spraying beans against the Mexican bean beetle with a wheelbarrow sprayer mounted on a slide.

In comparing results with different insecticides, the plant-injury factor as well as the insect-control factor must be taken into consideration. The plant-injury factor is apparent in yields harvested

FIG. 14.—Spraying small field beans with a hand sprayer to control the Mexican bean beetle.

when infestation is light, but in some cases does not show, except by comparison, when yield is heavy. The notes taken during the experiments showing observations of visible injury give very accurate data

on this point. This is shown in experiments performed under conditions of light infestation, with the possible exception of the zinc arsenite experiments. Injury by this insecticide is not easily estimated by observation. When infestation by the Mexican bean

FIG. 15.—Dusting beans with a knapsack bellows type of duster.

beetle is light, variations in yield are attributed to insecticide treatment, which often causes a decrease in yield. Each experiment must be compared with check plats and other plats tested at the same time, because of variations in land, season, and climatic factors.

FIG. 16.—Power duster used in experiments in control of the Mexican bean beetle.

Under typical conditions in the Southeast, summer crops of bush beans do not produce well.

In experiments where injury from treatment was serious, beetle injury would not be estimated.

In dust experiments, treatments in some instances followed closely on account of frequent heavy rains.

In experiment 1(c) the pulverized stone lime was not ground sufficiently to obtain a good application, and the amount applied was therefore excessive, as much dust fell to the ground.

The per cent of reduction in yields due to treatment, with the check plat as the basis, does not take into consideration bean beetle injury to the check, for in all experiments where this calculation is made Epilachna injury did not reduce yields to a very great extent. The insecticide injury as affecting yields therefore is shown rather lower in this column than is actually the case, for there is no way of accurately determining the reduction in yield in the absence of insect-free checks.

Check plats, except in a very few instances, were of the same size as the treated plats. In some cases two check plats were used, each the same size as the treated plats.

TABLE 11.—*Experiments with arsenicals commercially available, including sprays and dusts, for control of the Mexican bean beetle, 1922.*

Experiment No.	Insecticide used. (Dusts, pounds of materials; sprays, pounds of materials per 100 gallons rain water, unless otherwise noted.)	Rate applied per acre.	Size of plot.	Date of applications (1922).					Effect on yield, check plat basis.		Injury to foliage.			Infestation.
				1	2	3	4	5	Increase.	Reduction.	Insecticide.	Insect. Treated.	Insect. Check.	
		Gallons.	*Acres.*						*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	
1(a)[1]	Basic lead arsenate 2½ pounds (commercial).	116	0.05								0		40	Medium.
1(a)[1]	Magnesium arsenate 2 pounds, caseinate of lime 1 pound.	116	.05								5	0	40	Do.
1(a)[1]	Zinc arsenite 1½ pounds, caseinate of lime 1 pound.	116	.05	Apr. 21	May 6	May 12	May 20			40	25	0	40	Do.
1(a)[1]	Calcium arsenate 1½ pounds, rock lime 3 pounds.	116	.05							25	30	0	40	Do.
1(a)[1]	Lead arsenate 2 pounds	116	.05							31	40	0	40	Do.
		Pounds.												
1(b)[2]	Lead arsenate	14	.043							59	60		25	Light.
1(b)[2]	Lead arsenate 1 pound, hydrated lime 1 pound.	13	.043							38	60		25	Do.
1(b)[2]	Lead arsenate 1 pound, hydrated lime 4 pounds.	19	.043							37	30		25	Do.
1(b)[2]	Lead arsenate 1 pound, hydrated lime 9 pounds.	18	.043							15	25		25	Do.
1(b)[2]	Calcium arsenate	10	.043							60	35		25	Do.
1(b)[2]	Calcium arsenate 1 pound, hydrated lime 1 pound.	19	.043	May 6	May 10	May 16	May 20	May 26		60	20		25	Do.
1(b)[2]	Calcium arsenate 1 pound, pyrethrum powder 1 pound.	18	.043							40	35		25	Do.
1(b)[2]	Calcium arsenate 1 pound, hydrated lime 4 pounds.	19	.043							30	10		25	Do.
1(b)[2]	Calcium arsenate 1 pound, hydrated lime 9 pounds.	18	.043						13		0			Do.
1(b)[2]	Basic lead arsenate	17	.043						18		0	0	25	Do.
1(c)[1]	Basic lead arsenate paste[3] 6 pounds		.043	May 6	May 12	May 20					0			Do.
1(c)[2]	Calcium arsenate 1 pound, pulverized stone lime 1 pound.		.043	May 16	May 20	May 26					55			Do.
		Gallons.												
2[4]	Lead arsenate 2 pounds	70	.005	May 23							25	5	90	Very heavy.
		Pounds.												
2[4]	Lead arsenate 2 pounds, water from stream.	70	.005								15	5	90	Do.

3[2]	Calcium arsenate 1 pound, gypsum 1 pound.	15 est.	.004						....	....	15	....	....	Medium.
3[2]	Calcium arsenate 1 pound, sulphur[5] 1 pound.	15 est.	.004						....	....	20	....	....	Do.
3[2]	Calcium arsenate 1 pound, sulphur[5] 1 pound, hydrated lime 1 pound.	15 est.	.004	May 26	....	....	....	....	....	....	0	....	....	Do.
3[2]	Calcium arsenate 1 pound, gypsum 1 pound, hydrated lime 3 pounds.	15 est.	.004						....	....	0	....	....	Do.
4[6]	Lead arsenate 1 pound, hydrated lime 4 pounds.	25	.21						....	56	75	10	70	Heavy.
4[6]	Lead arsenate 1 pound, hydrated lime 9 pounds.	....	.21						23	....	15	10	70	Do.
4[6]	Calcium arsenate 1 pound, sulphur[5] 1 pound, hydrated lime 1 pound.	....	.1						....	16	20	10	70	Do.
4[6]	Calcium arsenate 1 pound, hydrated lime 5 pounds.	....	.21	June 14	June 25	July 7	....	....	15	....	25	10	70	Do.
4[6]	Calcium arsenate 1 pound, sulphur[5] 1 pound, hydrated lime 4 pounds.	....	.1						46	....	10	10	70	Do.
4[6]	Calcium arsenate 1 pound, hydrated lime 9 pounds.	....	.21						60	....	10	10	70	Do.
4[6]	Basic lead arsenate	....	.21						....	3	0	10	70	Do.
5[2]	Lead arsenate 1 pound, hydrated lime 1 pound.	50	.013						....	....	35	25	70	Do.
5[2]	Calcium arsenate 1 pound, hydrated lime 1 pound.	43	.013						....	....	25	25	70	Do.
5[2]	Calcium arsenate 1 pound, pulverized stone lime 1 pound.	53	.025	June 17	June 25	July 10	....	....	....	....	40	25	70	Do.
5[2]	Calcium arsenate 1 pound, gypsum 1 pound, hydrated lime 3 pounds.	37	.013						....	....	15	25	70	Do.
5[2]	Zinc arsenite	18	.013						....	....	60	25	70	Do.
		Gallons.												
6[6]	Magnesium arsenate 2 pounds, caseinate of lime 1 pound.	75–90	.18						1,034	....	0	20	100	Very heavy.
6[6]	Zinc arsenite $1\frac{1}{2}$ pounds, caseinate of lime 1 pound.	75–90	.18						285	....	20	0	100	Do.
6[6]	Basic lead arsenate $2\frac{1}{2}$ pounds (commercial).	75–90	.18	July 1	July 7	July 20	July 27	....	70	....	0	90	100	Do.
6[6]	Basic lead arsenate paste[3] 6 pounds	75–90	.18						356	....	0	80	100	Do.
7[1]	Lead arsenate 2 pounds	80	.033						1,312	....	40	15	100	Do.
7[1]	Zinc arsenite $1\frac{1}{2}$ pounds, caseinate of lime 1 pound.	80	.033						1,715	....	0	15	100	Do.
7[1]	Calcium arsenate $1\frac{1}{2}$ pounds, rock lime 3 pounds.	80	.033	July 1	July 7	July 20	July 27	....	1,715	....	0	15	100	Do.
7[1]	Basic lead arsenate $2\frac{1}{2}$ pounds, caseinate of lime 1 pound.	80	.033						505	....	0	60	100	Do.

[1] Wheelbarrow sprayer used.
[2] Hand knapsack bellows duster used.
[3] Prepared in laboratory.
[4] Hand sprayer used.
[5] Dusting sulphur used in each case.
[6] Power equipment used.

TABLE 11.—*Experiments with arsenicals commercially available, including sprays and dusts, for control of the Mexican bean beetle, 1922*—Contd.

Experiment No.	Insecticide used. (Dusts, pounds of materials, sprays, pounds of materials per 100 gallons rain water, unless otherwise noted.)	Rate applied per acre.	Size of plot.	Date of applications (1922).					Effect on yield, check plat basis.		Injury to foliage.			Infestation.
				1	2	3	4	5	Increase.	Reduction.	Insecticide.	Insect. Treated.	Insect. Check.	
		Gallons.	*Acres.*						*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	
10 [2]	Calcium arsenate 1 pound, hydrated lime 5 pounds.	....	.012						....	....	25	15	100	Very heavy.
10 [2]	Calcium arsenate 1 pound, sulphur [5] 1 pound, hydrated lime 4 pounds.	....	.012	July 10	July 18	July 21	July 28	....	....	....	20	15	100	Do.
10 [2]	Magnesium arsenate	....	.012						....	....	0	15	100	Do.
11 [2]	Lead arsenate 1 pound, hydrated lime 1 pound.	....	.004						....	47	30	10	35	Medium.
11 [2]	Lead arsenate 1 pound, hydrated lime 2 pounds.	....	.004						11	....	30	10	35	Do.
11 [2]	Lead arsenate 1 pound, hydrated lime 3 pounds.	....	.004						136	....	25	10	35	Do.
11 [2]	Lead arsenate 1 pound, hydrated lime 5 pounds.	....	.004						46	....	0	10	35	Do.
11 [2]	Calcium arsenate 1 pound, hydrated lime 1 pound.	....	.004	July 22	July 28	Aug. 4	Aug. 11	....	206	....	60	5	35	Do.
11 [2]	Calcium arsenate 1 pound, sulphur [5] 1 pound.	....	.004						53	....	50	10	35	Do.
11 [2]	Calcium arsenate 1 pound, sulphur [5] 1 pound, hydrated lime 1 pound.	....	.004						141	....	10	10	35	Do.
11 [2]	Calcium arsenate 1 pound, hydrated lime 5 pounds.	....	.004						189	....	0	15	35	Do.
11 [2]	Basic lead arsenate	....	.004						6	....	0	10	35	Do.
12 [4]	Lead arsenate 2 pounds	....	.006						72	....	40	10	35	Do.
12 [4]	Lead arsenate 2 pounds, water from stream.	....	.006	July 25	Aug. 2	Aug. 10	....	....	....	18	65	0	35	Do.
12 [4]	Basic lead arsenate 2½ pounds (commercial).	70	.006						208	....	0	10	35	Do.
		Pounds.												
14 [6]	Calcium arsenate 1 pound, hydrated lime 5 pounds.	23	.21						....	38	0	....	....	Very light.
14 [6]	Calcium arsenate 1 pound, sulphur [5] 1 pound, hydrated lime 4 pounds.	17	.21						....	([7])	0	....	....	Do.
14 [6]	Calcium arsenate 1 pound, hydrated lime 9 pounds.	22	.21						....	([7])	0	....	....	Do.
14 [6]	Magnesium arsenate	15	.21	Aug. 15	Aug. 22	Sept. 8	Sept. 15	....	....	24	0	....	....	Do.
14 [6]	Magnesium arsenate 1 pound, hydrated lime 1 pound.	18	.21						11	....	0	....	....	Do.
14 [6]	Magnesium arsenate 1 pound, hydrated lime 5 pounds.	22	.21						....	17	0	....	....	Do.
14 [6]	Basic lead arsenate	19	.21						....	([7])	0	....	....	Do.

		Gallons.												
15 [6]	Magnesium arsenate 2 pounds, caseinate of lime 1 pound.	125	.118						38	....	0	....	....	Do.
15 [6]	Zinc arsenite 1½ pounds, caseinate of lime 1 pound.	125	.118						....	24	0	....	....	Do.
15 [6]	Calcium arsenate 1½ pounds, rock lime 3 pounds.	125	.118	Aug. 15	Aug. 22	Sept. 8	Sept. 15	....	33	....	0	....	....	Do.
15 [6]	Basic lead arsenate 4 pounds, caseinate of lime 1 pound.	125	.118						109	....	0	....	....	Do.
15 [6]	Basic lead arsenate paste [3] 6 pounds......	125	.06						....	4	0	....	....	Do.
		Pounds.												
17 [2]	Magnesium arsenate......................	20	.02						17	....	0	....	....	Do.
17 [2]	Magnesium arsenate 1 pound, hydrated lime 1 pound.	15	.02						6	....	0	....	....	Do.
17 [2]	Magnesium arsenate 1 pound, hydrated lime 3 pounds.	14	.02						7	....	0	....	....	Do.
17 [2]	Magnesium arsenate 1 pound, hydrated lime 5 pounds.	17	.02	Aug. 16	Aug. 23	Sept. 9	Sept. 15	....	25	....	0	....	....	Do.
17 [2]	Magnesium arsenate 1 pound, hydrated lime 7 pounds.	13	.02						1	....	0	....	....	Do.
17 [2]	Magnesium arsenate 1 pound, hydrated lime 9 pounds.	12	.02						....	17	0	....	....	Do.

[2] Hand knapsack bellows duster used.
[3] Prepared in laboratory.
[4] Hand sprayer used.
[5] Dusting sulphur used in each case.
[6] Power equipment used.
[7] Reductions in yields were due largely to inferior crop on one portion of the field due to soil. As noted, no visible injury occurred.

NOTE.—Spray machines were run at the following pressures: Power, 250 pounds; wheelbarrow, 150 pounds; hand, 40 to 65 pounds.

TABLE 12.—*Experiments with dusts for control of the Mexican bean beetle, 1922.*

Experiment No.	Insecticide used.	Rate applied per acre.	Size of plat.	Date of application (1922). 1	2	3	4	5	Insecticide injury to foliage.	Reduction in yield due to treatment; check plat as basis.	Bean beetle injury to foliage. Treated.	Check.	Increase in yield over check plat.	Infestation.
		Pounds	*Acres.*						*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	
1(b)[1]	Lead arsenate, unmixed	14	0.043	May 6	May 10	May 16	May 20	May 26	60	59		25		Light.
1(b)[1]	Lead arsenate 1 pound, hydrated lime 1 pound.	13	.043	May 6	May 10	May 16	May 20	May 26	60	38		25		Do.
5[1]	....do	50	.013	June 17	June 25	July 10			35		25	70		Heavy.
11[1]	....do		.004	July 22	July 28	Aug. 4	Aug. 11		30	47	10	35		Medium.
11[1]	Lead arsenate 1 pound, hydrated lime 2 pounds.		.004	July 22	July 28	Aug. 4	Aug. 11		30		10	35	11	Do.
11[1]	Lead arsenate 1 pound, hydrated lime 3 pounds.		.004	July 22	July 28	Aug. 4	Aug. 11		25		10	35	136	Do.
1(b)[1]	Lead arsenate 1 pound, hydrated lime 4 pounds.	19	.043	May 6	May 10	May 16	May 20	May 26	30	37		25		Light.
4[2]	....do	25	.21	June 14	June 25	July 7			75	56	10	70		Heavy.
11[1]	Lead arsenate 1 pound, hydrated lime 5 pounds.		.004	July 22	July 28	Aug. 4	Aug. 11		0		10	35	46	Medium.
1(b)[1]	Lead arsenate 1 pound, hydrated lime 9 pounds.	18	.043	May 6	May 10	May 16	May 20	May 26	25	15		25		Light.
4[2]	....do		.21	June 14	June 25	July 7			15		10	70	23	Heavy.
1(b)[1]	Calcium arsenate, unmixed	10	.043	May 6	May 10	May 16	May 20	May 26	35	60		25		Light.
1(b)[1]	Calcium arsenate 1 pound, hydrated lime 1 pound.	19	.043	May 6	May 10	May 16	May 20	May 26	20	60		25		Do.
5[1]	....do	43	.013	June 17	June 25	July 10			25		25	70		Heavy.
11[1]	....do		.004	July 22	July 28	Aug. 4	Aug. 11		60		5	35	206	Medium.
1(c)[1]	Calcium arsenate 1 pound, stone lime [3] 1 pound.		.043	May 16	May 20	May 26			55					Light.
5[1]	....do.[3]	53	.025	June 17	June 25	July 10			40		25	70		Heavy.
3[1]	Calcium arsenate 1 pound, gypsum 1 pound.	[4] 15	.004	May 26					15					Medium.
3[1]	Calcium arsenate 1 pound, sulphur [5] 1 pound.	[4] 15	.004	May 26					20					Do.
11[1]	....do.[5]		.004	July 22	July 28	Aug. 4	Aug. 11		50		10	35	53	Do.
1(b)[1]	Calcium arsenate 1 pound, pyrethrum powder 1 pound.	18	.043	May 6	May 10	May 16	May 20	May 26	35	40		25		Light.
3[1]	Calcium arsenate 1 pound, sulphur [5] 1 pound, hydrated lime 1 pound.	[4] 15	.004	May 26					0					Medium.
4[2]	....do.[5]		.1	June 14	June 25	July 7			20	16	10	70		Heavy.
11[1]	....do.[5]		.004	July 22	July 28	Aug. 4	Aug. 11		10		10	35	141	Medium.

1(b)[1]	Calcium arsenate 1 pound, hydrated lime 4 pounds.	19	.043	May 6	May 10	May 16	May 20	May 26	10	30	....	25	....	Light.
3[1]	Calcium arsenate 1 pound, gypsum 1 pound, hydrated lime 3 pounds.	[4] 15	.004	May 26	....	....	....	....	....	....	....	....	....	Medium.
5[1]	.....do.....	37	.013	June 17	June 25	July 10	....	....	15	....	25	70	....	Heavy.
4[2]	Calcium arsenate 1 pound, hydrated lime 5 pounds.	....	.21	June 14	June 25	July 7	....	....	25	....	10	70	15	Do.
11[1]	.....do.....	....	.004	July 22	July 28	Aug. 4	Aug. 11	....	0	....	15	35	189	Medium.
14[2]	.....do.....	23	.21	Aug. 15	Aug. 22	Sept. 8	Sept. 15	....	0	38	....	....	....	Very light.
10[1]	.....do.....	....	.012	July 10	July 18	July 21	July 28	....	25	....	15	100	....	Very heavy.
4[2]	Calcium arsenate 1 pound, sulphur[5] 1 pound, hydrated lime 4 pounds.	....	.1	June 14	June 25	July 7	....	....	10	....	10	70	46	Heavy.
14[2]	.....do.[5].....	17	.21	Aug. 15	Aug. 22	Sept. 8	Sept. 15	....	0	(6)	....	....	....	Very light.
10[1]	.....do.[5].....	....	.012	July 10	July 18	July 21	July 28	....	20	....	15	100	....	Very heavy.
1(b)[1]	Calcium arsenate 1 pound, hydrated lime 9 pounds.	18	.043	May 6	May 10	May 16	May 20	May 26	0	....	....	....	13	Light.
4[2]	.....do.....	....	.21	June 14	June 25	July 7	....	....	10	....	10	70	60	Heavy.
14[2]	.....do.....	22	.21	Aug. 15	Aug. 22	Sept. 8	Sept. 15	....	0	(6)	....	....	....	Very light.
10[1]	Magnesium arsenate, unmixed.....	....	.012	July 10	July 18	July 21	July 28	....	0	....	15	100	....	Very heavy.
14[2]	.....do.....	15	.21	Aug. 15	Aug. 22	Sept. 8	Sept. 15	....	0	24	....	....	....	Very light.
17[1]	.....do.....	20	.02	Aug. 16	Aug. 23	Sept. 9	Sept. 15	....	0	....	....	....	17	Do.
14[2]	Magnesium arsenate 1 pound, hydrated lime 1 pound.	18	.21	Aug. 15	Aug. 22	Sept. 8	Sept. 15	....	0	....	....	....	11	Do.
17[1]	.....do.....	15	.02	Aug. 16	Aug. 23	Sept. 9	Sept. 15	....	0	....	....	....	6	Do.
17[1]	Magnesium arsenate 1 pound, hydrated lime 3 pounds.	14	.02	Aug. 16	Aug. 23	Sept. 9	Sept. 15	....	0	....	....	....	7	Do.
14[2]	Magnesium arsenate 1 pound, hydrated lime 5 pounds.	22	.21	Aug. 15	Aug. 22	Sept. 8	Sept. 15	....	0	17	....	....	....	Do.
17[1]	.....do.....	17	.02	Aug. 16	Aug. 22	Sept. 9	Sept. 15	....	0	....	....	....	25	Do.
17[1]	Magnesium arsenate 1 pound, hydrated lime 7 pounds.	13	.02	Aug. 16	Aug. 23	Sept. 9	Sept. 15	....	0	....	....	....	1	Do.
17[1]	Magnesium arsenate 1 pound, hydrated lime 9 pounds.	12	.02	Aug. 16	Aug. 23	Sept. 9	Sept. 15	....	0	17	....	....	....	Do.
1(b)[1]	Basic lead arsenate, unmixed.....	17	.043	May 6	May 10	May 16	May 20	May 26	0	....	0	25	18	Light.
4[2]	.....do.....	....	.21	June 14	June 25	July 7	....	....	0	3	10	70	....	Heavy.
11[1]	.....do.....	....	.004	July 22	July 28	Aug. 4	Aug. 11	....	0	....	10	35	6	Medium.
14[2]	.....do.....	19	.21	Aug. 15	Aug. 22	Sept. 8	Sept. 15	....	0	(6)	....	....	....	Very light.
5[1]	Zinc arsenite, unmixed.....	18	.013	June 17	June 25	July 10	....	....	60	....	25	70	....	Heavy.

[1] Hand knapsack bellows duster used.
[2] Power duster used.
[3] Pulverized stone lime used.
[4] Estimated.
[5] Dusting sulphur used in each case.
[6] Reductions in yield were due largely to an inferior crop on a portion of the field due to soil. As noted in preceding column, no visible injury occurred.

TABLE 13.—*Experiments with sprays for control of the Mexican bean beetle, 1922.*

Experiment No.	Insecticide used. (Materials and number of pounds of each per 100 gallons rain water unless otherwise noted.)	Rate applied per acre.	Size of plat.	Date of applications (1922). 1	2	3	4	Insecticide injury to foliage.	Reduction in yield due to treatment, check plat as basis.	Bean beetle injury to foliage. Treated.	Check.	Increase in yield over check plat.	Infestation.
		Gallons.	Acres.					Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	
1(a)[1]	Lead arsenate 2 pounds	116	0.05	Apr. 21	May 6	May 12	May 20	40	31	0	40		Medium.
2[2]	do	70	.005	May 23				25		5	90		Very heavy.
2[2]	do.[3]	70	.005	May 23				15		5	90		Do.
7[1]	do	80	.033	July 1	July 7	July 20	July 27	40		15	100	1,312	Do.
12[2]	do		.006	July 25	Aug. 2	Aug. 10		40		10	35	72	Medium.
12[2]	do.[3]		.006	July 25	Aug. 2	Aug. 10		65		0	35		Do.
1(a)[1]	Magnesium arsenate 2 pounds, caseinate lime 1 pound	116	.05	Apr. 21	May 6	May 12	May 20	5		0	40		Do.
6[4]	do	75-90	.18	July 1	July 7	July 20	July 27	0		20	100	1,034	Very heavy.
15[4]	do	125	.118	Aug. 15	Aug. 22	Sept. 8	Sept. 15	0				38	Very light.
16[2]	Magnesium arsenate 2 pounds		.014	Aug. 16	Aug. 23	Sept. 9	Sept. 15	0					Do.
	Magnesium arsenate 3 pounds		.014	Aug. 16	Aug. 23	Sept. 9	Sept. 15	0					Do.
	Magnesium arsenate 4 pounds		.014	Aug. 16	Aug. 23	Sept. 9	Sept. 15	0					
	Magnesium arsenate 5 pounds		.014	Aug. 16	Aug. 23	Sept. 9	Sept. 15	0					
	Magnesium arsenate 6 pounds		.014	Aug. 16	Aug. 23	Sept. 9	Sept. 15	0					
	Magnesium arsenate 8 pounds		.014	Aug. 16	Aug. 23	Sept. 9	Sept. 15	0					
	Magnesium arsenate 10 pounds		.014	Aug. 16	Aug. 23	Sept. 9	Sept. 15	0					
	Magnesium arsenate 3 pounds, fish-oil soap 1 pound		.014	Aug. 16	Aug. 23	Sept. 9	Sept. 15	0					
	Magnesium arsenate 3 pounds, oil emulsion 1 gallon		.013	Aug. 16	Aug. 23	Sept. 9	Sept. 15	0					
	Magnesium arsenate 3 pounds, caseinate lime 1 pound		.013	Aug. 16	Aug. 23	Sept. 9	Sept. 15	0					
	Magnesium arsenate 3 pounds[3]		.013	Aug. 16	Aug. 23	Sept. 9	Sept. 15	0					
1(a)[1]	Zinc arsenite 1½ pounds, caseinate lime 1 pound	116	.05	Apr. 21	May 6	May 12	May 20	25	40	0	40		Medium.
6[4]	do	75-90	.18	July 1	July 7	July 20	July 27	20		0	100	285	Very heavy.
7[1]	do	80	.033	July 1	July 7	July 20	July 27	0		15	100	1,715	Do.
15[4]	do	125	.118	Aug. 15	Aug. 22	Sept. 8	Sept. 15	0	24				Very light.
1(a)[1]	Calcium arsenate 1½ pounds, rock lime 3 pounds	116	.05	Apr. 21	May 6	May 12	May 20	30	25	0	40		Medium.
7[1]	do	80	.033	July 1	July 7	July 20	July 27	0		15	100	1,715	Very heavy.
15[4]	do	125	.118	Aug. 15	Aug. 22	Sept. 8	Sept. 15	0				33	Very light.
1(a)[1]	Basic lead arsenate 2½ pounds (commercial)	116	.05	Apr. 21	May 6	May 12	May 20	0			40		Medium.
6[4]	do	75-90	.18	July 1	July 7	July 20	July 27	0		90	100	70	Very heavy.
7[1]	Basic lead arsenate 2½ pounds, caseinate lime 1 pound	80	.033	July 1	July 7	July 20	July 27	0		60	100	505	Do.

12[2]	Basic lead arsenate 2½ pounds	70	.006	July 25	Aug. 2	Aug. 10	....	0	....	10	35	208	Medium.
	Basic lead arsenate 3 pounds	70	.006	July 25	Aug. 2	Aug. 10	....	0	....	10	35	182	Do.
	Basic lead arsenate 3½ pounds	70	.006	July 25	Aug. 2	Aug. 10	....	0	....	15	35	190	Do.
	Basic lead arsenate 4 pounds	70	.006	July 25	Aug. 2	Aug. 10	....	0	....	20	35	63	Do.
	Basic lead arsenate 5 pounds	70	.006	July 25	Aug. 2	Aug. 10	....	20	....	....	35	117	Do.
	Basic lead arsenate 6 pounds	70	.006	July 25	Aug. 2	Aug. 10	....	20	....	10	35	100	Do.
	Basic lead arsenate 10 pounds	70	.006	July 25	Aug. 2	Aug. 10	....	50	....	....	35	17	Do.
	Basic lead arsenate 2½ pounds[3]	70	.006	July 25	Aug. 2	Aug. 10	....	0	....	15	35	199	Do.
	Basic lead arsenate 10 pounds[3]	70	.006	July 25	Aug. 2	Aug. 10	....	75	....	....	35	8	Do.
15[4]	Basic lead arsenate 4 pounds, caseinate lime 1 pound	125	.118	Aug. 15	Aug. 22	Sept. 8	Sept. 15	0	....	....	....	109	Very light.
1(c)[1]	Basic lead arsenate paste 6 pounds[5]	....	.043	May 6	May 12	May 20	....	0	....	....	....	....	Light.
6[4]	....do.[5]	75–90	.18	July 1	July 7	July 20	July 27	0	....	80	100	356	Very heavy.
15[4]	....do.[5]	125	.06	Aug. 15	Aug. 22	Sept. 8	Sept. 15	0	4	....	....	....	Very light.
1(c)[1]	Lead arsenate 1 pound, zinc carbonate 1, 4 pounds	....	.043	May 6	May 12	May 20	....	0	....	....	....	....	Light.
2[2]	....do	70	.005	May 23	....	....	....	0	....	5	90	....	Very heavy.
2[2]	....do.[3]	70	.005	May 23	....	....	....	0	....	5	90	....	Do.
2[2]	Lead arsenate 4 pounds, zinc carbonate 1, 2½ pounds	70	.005	May 23	....	....	....	0	....	5	90	....	Do.
2[2]	....do.[3]	70	.005	May 23	....	....	....	0	....	5	90	....	Do.

[1] Wheelbarrow sprayer used.
[2] Hand sprayer used.
[3] Water obtained from stream.
[4] Power sprayer used.
[5] Prepared in laboratory.

NOTE.—Spray machines were run at the following pressures: Power, 250 pounds; wheelbarrow, 150 pounds; hand, 40 to 65 pounds.

MAGNESIUM ARSENATE.

Magnesium arsenate has proved to be the least toxic to the bean plant of all the materials tested, and it is at the same time toxic to the bean beetle. For two seasons no appreciable injury has resulted from its use in 134 treatments in the field.

As a spray at 2 pounds per acre with caseinate of lime, it has given excellent control. Rain water is not necessary; well water and water from streams do not cause injury to foliage, even though the content of sodium salts is relatively high. When magnesium arsenate was used, increases in yields generally resulted, but slight reductions occurred in a few experiments when bean beetle injury was very light.

Experiment 6 (Table 11) gives a good idea of the merits of this material in comparison with zinc arsenite and basic lead arsenate, and the relative merits of the latter in comparison with calcium arsenate are shown in experiment 7 (Table 11). The check plat in experiment 6 was completely destroyed, while the adjacent plat treated with magnesium arsenate remained green and bore a good crop. (Pl. XII, *A*, *B*.)

Magnesium arsenate is also safe for use as a dust. On account of poor physical properties it should be diluted with from 1 to 5 parts of hydrated lime, depending on the infestation. Further work with this material as a dust is necessary.

This arsenical, as at first placed on the market, was very high in water-soluble arsenic content, but the method of manufacture has been improved and all the results reported herein were obtained with a high grade of material which did not exceed 0.13 per cent water-soluble arsenic content, expressed as metallic arsenic. The toxicity of this material to the Mexican bean beetle compares very closely with that of calcium arsenate. Caseinate of lime as a spreader, added at the rate of half as much by weight as the arsenical, may be used with this material when applied as a spray.

BASIC LEAD ARSENATE.

Basic lead arsenate is probably the safest commercial material for use on bean foliage when mixed with rain water. It does not cause injury to foliage when used as a dust. Its low toxicity to the bean beetle makes it very undesirable. In one instance 90 per cent of the field treated with this material was destroyed, and could hardly be distinguished from the untreated field. Laboratory-prepared material gave similar results. In other instances, under conditions of light infestation, this material gave sufficient protection and yields were notably increased. In one experiment this material was used at the rate of 4 pounds per acre, as a spray, without injury to the bean foliage. Further experiments are necessary to determine the degree of control which can be obtained at this rate of application.

Basic lead arsenate is the commercial basic lead arsenate such as is used in certain districts of California, and is termed "4, 1, 3, 1-lead-hydroxy arsenate, $Pb_4(PbOH)(AsO_4)_3, H_2O$" by McDonnell and Smith.[9]

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[9] Jour. Amer. Chem. Soc., vol. 38, No. 10, October, 1916, p. 2030.

ZINC ARSENITE.

The two commercial grades of zinc arsenite experimented with the past two seasons are unsafe for use on bean foliage. Zinc arsenite does not appear to be as injurious to bean foliage as lead arsenate. The injury to the bean plant is different from that caused by other arsenicals, as burning of the foliage does not always result, but the plant is visibly stunted, the color of the foliage turns darker green, and the leaves show a tendency to curl.

Used as a spray at 1½ pounds to the acre, reductions in yield below those of check plats were obtained. Under conditions of severe infestation, excellent insect control is apparently obtained, but treated fields do not yield well. On account of the particular type of injury to the crop from use of this arsenical, the injury is likely to be overlooked and the arsenical rated too high unless accurate records of yields are obtained.

Only one experiment was performed with this material as a dust during 1922. Diluted with hydrated lime, plant injury can be reduced, but this material is inferior to calcium arsenate and magnesium arsenate on account of toxicity to foliage. It is also physically inferior to calcium arsenate for dusting.

CALCIUM ARSENATE.

Calcium arsenate or arsenate of lime is extremely toxic to bean foliage. Injury to foliage when used as a dust ranged from 60 per cent to no injury, depending to a great extent on the degree of dilution with hydrated lime. Reductions in yield occurred in much the same order. It is certain that calcium arsenate can not be used as a dust stronger than 1 to 5 parts of hydrated lime, and that appreciable injury may result in some cases with this dilution.

This insecticide is the most desirable for dusting, from the standpoint of physical properties.

Sulphur as a diluent appears to have a slight beneficial effect in reducing plant injury, but not enough to make calcium arsenate safe at stronger than the 1–1–4 dilution shown in the next paragraph, and foliage injury occurred in two experiments to the extent of 10 and 20 per cent, respectively. The beneficial action of sulphur is even less noticeable when calcium arsenate is used in greater proportions.

Excellent results have been obtained with a mixture devised by Dr. F. L. Thomas, of the Alabama Agricultural Experiment Station, comprising 1 part of calcium arsenate, 1 part of superfine dusting sulphur, and 4 parts of hydrated lime. Slight injury, however, has occurred under certain conditions with this mixture. Where this occurs, it is suggested that the hydrated lime content be increased.

Diluted with 9 parts of hydrated lime, the high-grade calcium arsenate used has for two seasons been found safe on bean foliage. Only one instance of injury to foliage occurred, and that only 10 per cent. Further comparisons between this cheap mixture of materials, available to most growers, and the more expensive sulphur mixture are necessary. The slight advantage of this mixture over a 1 to 9 hydrated lime mixture does not warrant the extra expense, where growers have to purchase this mixture already prepared, since the price is from 2 to 4 times as high per unit of arsenical as

a home-mixed material. Where dusting sulphur is available, it is recommended that the grower obtain the ingredients and mix them himself.

Used as a spray, calcium arsenate is unsafe without an excess of lime. At the rate of 1½ pounds per acre, with 3 pounds of rock lime freshly slaked, or hydrated lime, it is comparatively safe. In two experiments no plant injury occurred, and excellent control was obtained. In experiment 1(a) (Table 11) 30 per cent of foliage injury occurred, however, and it should not be used when magnesium arsenate is available. In experiment 7 results identical with those following the use of zinc arsenite were obtained.

The calcium arsenate used in all these experiments was of the very highest grade. The water-soluble arsenic content of this material did not in any case exceed 0.13 per cent, expressed as metallic arsenic. Inferior grades of this compound should be very cautiously applied. The bean plant is more susceptible to arsenical injury than the cotton plant, and grades suitable for cotton dusting may not be suitable for use on beans.

LEAD ARSENATE.

For two seasons lead arsenate proved too injurious to bean foliage to warrant its use in the Southeastern States. Under conditions of severe infestation, the protection afforded the foliage is sufficient to make it appear that good results are obtained, but the arsenical injury is serious enough to reduce greatly the normal yield.

Injury to foliage from lead arsenate used as a dust ranged from 60 per cent with the material undiluted to 15 per cent when diluted with 9 parts of hydrated lime. The reduction in yield ranged from 59 to 15 per cent below untreated checks which were injured by the bean beetle from 25 to 70 per cent. Slight increases in yield resulted from treatment under conditions of medium and heavy infestation when injury by the bean beetle to untreated checks was 35 to 70 per cent. The previous season this material was even more injurious, and experiments were therefore reduced during the second season.

Injury to foliage from lead arsenate as a spray at 2 pounds per acre ranged from 25 to 40 per cent when rain water was used, and from 15 to 65 per cent when water from a stream was used. A reduction of 31 per cent in yield occurred under conditions of medium infestation when the untreated check plat was injured 40 per cent by the bean beetle. It is quite possible that lead arsenate can be used more successfully in the North when the beetle reaches that section, but in the Southeast it is unsafe. Rain water should be used in sections where the water contains soluble salts which decompose lead arsenate and cause an increase in soluble arsenic.

Lead arsenate corrected with zinc carbonate, according to suggestions from Dr. William Moore, may probably be used successfully on beans. Additional work on this point is necessary.

This arsenical is more repellent to the adult bean beetle than magnesium arsenate, zinc arsenite, or calcium arsenate.

The lead arsenate referred to is a good grade of the commercial lead arsenate, or di-lead arsenate, which is termed "dilead orthoarsenate, $PbHAsO_4$," by McDonnell and Smith.[10]

[10] Jour. Amer. Chem. Soc., vol. 38, No. 10, October, 1916, p. 2030.

USE OF SPRAYED BEANS AS FOOD.

For two seasons beans treated with arsenicals have been analyzed for arsenical deposits. In no case has the amount of arsenic per quart of green snap beans as picked approached the point where there is any danger whatever from consumption of even this amount. Snap beans which have been treated should be washed in two changes of clear water before marketing to safeguard against any difficulty from this source. In accordance with ordinary cleanliness, beans should be thoroughly washed before cooking. There is not the remotest danger from dried beans. Bean-vine hay which has been treated with arsenicals must not be fed to stock.

COST OF TREATMENT.

Computations of the cost of treating an acre of beans, from records obtained on the experimental plats, give results as follows: Spraying costs from $4 to $8 per acre, depending on the costs of arsenicals and type of machine used; dusting costs from $4.50 to $12 per acre, depending chiefly on the prices of arsenicals and the type of machine used. These figures are based on four treatments of bush beans drilled in rows 3 feet apart.

In these calculations, man labor is figured at 20 cents per hour and horse labor at 10 cents per hour. Where labor is higher, calculations may be made to suit conditions. From 4 to 8 hours are required to spray an acre of bush beans with a small hand sprayer, depending on the size of the beans. The wheelbarrow sprayer mounted on a slide and drawn by a horse requires the time of two men and one horse for 3 hours. The power sprayer requires two men and two horses for one-half hour each. The hand duster requires one man for 2½ hours. The power or traction duster requires 25 minutes time of one man and two horses, but this may be reduced on large acreages. Time of refilling machines is included in the above.

DISCUSSION OF ARTIFICIAL CONTROL.

Sprays, compared with dusts, have given consistently superior results for two seasons. Much of the difficulty with dusts is traceable to the manipulation of dusting machinery, which is not at present as suitable for treating the under surfaces of leaves on low crops as spraying machinery.

With the perfection of dusting machinery and methods of application, dusting will probably become a more desirable farm practice in many cases than spraying. Where growers are equipped with machinery for spraying, and are so situated that water can be easily obtained, better results will be obtained by this method. Spraying is not so dependent on weather conditions as dusting, since the adhesion of the spray to the leaf is greater and the material is not washed off the leaves by rains as easily as is the case with the dust. Again, spraying can be done under atmospheric conditions which are unsuitable for dusting. In many cases this makes it possible to obtain better control with one or two fewer applications of sprays than of dusts. The amount of the arsenical required per acre is of course much less with spraying than with dusting, and in view of the increasing price of arsenicals this factor is becoming more and more important.

Spraying has certain disadvantages, compared with dusting. Initial expenditures for equipment are greater in some cases, and more time per acre is required on account of refilling the machine, preparing the spray, and cleaning the nozzles.

Spraying has the distinct advantage that it makes the most efficient and economical use of magnesium arsenate, which is not especially adapted to dusting.

Magnesium arsenate has been found by several investigators to be injurious to the foliage of fruit trees. It will not, therefore, fill the place of an arsenical for general use. A high-grade material, however, will undoubtedly be safe for many uses.

Because of the availability of calcium arsenate and its superior dusting properties, it will be much used, and is recommended as a dust where no better material is at hand. Only a very high grade should be employed, and it should not be stronger than 1 to 9 parts of hydrated lime (or plasterers' lime).

When fine dusting sulphur is available, the 1–1–4 mixture of calcium arsenate, dusting sulphur, and hydrated lime is recommended. If injury to foliage results, the hydrated lime content should be doubled.

Lead arsenate and zinc arsenite should never be used on beans in the Southeast.

MIXING DUSTS.

Dusts may be mixed on the farm with very little trouble. Ingredients should be weighed. Quantities up to 100 pounds may be mixed with a steel drum which can be tightly covered. The drum should be filled not more than two-thirds full, covered tightly, and rolled about for a distance of approximately 50 feet. It should then be tipped up on each end and this process of rolling and tipping repeated 15 or 20 times. When ingredients are lumpy from standing, they should be sifted through at least a 50-mesh sieve before mixing. For large quantities, a ball mill or a baker's sifter and mixer may be used.

SUMMARY OF CONTROL RECOMMENDATIONS.

Magnesium arsenate, at the rate of 2 pounds to 100 gallons of water, is an effective spray. Caseinate of lime as a spreader may be used with this mixture at the rate of 1 pound to every 100 gallons of spray. Using three nozzles to the row on bush beans drilled in rows 3 feet apart, about 90 gallons of spray are required per acre with a power machine drawn by a team. About 2 pounds of the poison per acre is the proper dosage. Two nozzles should be directed to the under side of the leaves, and a pressure of 150 pounds or more is essential for good results. The nozzle over the top of the row need not be used in cases of light infestation or when pressure can not be maintained.

The spray should be applied when the eggs of the bean beetle become numerous, usually when the beans begin to send out their first trifoliate leaves; i. e., the third and fourth leaves.

Under conditions of heavy infestation four applications are necessary at intervals of from 7 to 10 days. Spray may be applied until the first bean pods are 2 or 3 inches long.

When spraying is impracticable, magnesium arsenate may be used as a dust diluted with from 1 to 5 parts of hydrated lime, depending

on the numbers of beetles present and the damage done. Another effective dust is composed of a high grade of calcium arsenate diluted with 9 parts of hydrated lime. A mixture of high-grade calcium arsenate 1 part, fine dusting sulphur 1 part, and hydrated lime 4 parts also is effective and may be substituted for magnesium arsenate when the ingredients are readily available to growers.

On bush beans drilled in rows 3 feet apart, dust should be applied at the rate of 15 pounds or a little less per acre. Dust should be applied when there is no wind blowing and to the under surface of the leaves. Dew is not essential, but best atmospheric conditions usually occur when dew is on the plants.

On small plantings up to 3 acres in size a knapsack type of hand-bellows duster with tube attached to a flexible hose gives best results. On larger plantings up to 5 to 10 acres, a 2-row duster with nozzles arranged to direct the dust to the under surface of the leaves should be used. One dusting to the row is sufficient except in very heavy infestations, when each row should be dusted from both sides. On larger plantings a power or traction 4-row duster is necessary. Beans should be planted in straight rows and at equal distances apart for all control operations where two or more rows are treated at once.

Where the beetle is numerous, bush beans should be planted. Pole beans mature too slowly and require too many applications to make control practicable.

SUMMARY.

The Mexican bean beetle is the most serious insect enemy of edible beans in the portions of the United States which it inhabits. It has long been present in the Southwest, and within the last few years has made its appearance in the Southeast. At the close of 1922 the infestation included portions of seven States in that section, including Alabama, Georgia, Kentucky, North Carolina, South Carolina, Tennessee, and Virginia. It is spreading northward rapidly and, as it is capable of long flights, may, in the course of a few years, extend its range over the whole central and eastern part of the United States.

The adult insect, or beetle, is copper-colored, bears eight black spots on each wing cover, and is about one-fourth of an inch long. The female lays orange-yellow eggs in masses of from 40 to 60 on the lower surfaces of the leaves, and in from 5 to 7 days during summer these hatch into small spiny orange-yellow larvæ, which when full-grown are about one-third of an inch long. The larval period is from 16 to 20 days long in summer. The larva transforms to pupa on the lower surface of a leaf, or on near-by weeds or other objects, and emerges as a beetle in 6 or 7 days, requiring in Alabama a total from egg to adult of 27 to 33 days during summer.

The Mexican bean beetle is extremely prolific. A maximum of four generations from first egg to first adult in each generation occurred in 1921 and 1922; that is, the earliest progeny of each generation was reared and four generations were produced. Two generations annually, with a possible third, may be considered the rule in the field, with the peak of the infestation during July and early August.

The beetles and larvæ feed on the under surface of the leaves of beans and other legumes, leaving a characteristic network of tissue,

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which soon dries. When beetles are abundant, beans are destroyed in two or three weeks. Since the larva consumes relatively greater quantities of leaf tissue than the beetle, the former is the more destructive stage. In many sections of the South this insect has destroyed entire bean crops in the last two years, and has caused serious damage one year after it has reached a new locality.

Winter is passed by the beetle in woodlands or sheltered places distant from the infested bean field; only a small proportion of overwintered adults remain in the field. They tend to hibernate gregariously. Most suitable hibernation quarters in the Southeast are on wooded slopes where accumulations of leaves or pine needles offer protection and relatively constant moisture conditions.

The Mexican bean beetle, while primarily a bean pest, is able to reproduce on beggarweed, cowpeas, soy beans, and a few other plants.

Where the bean beetle thrives, control measures are essential.

The bean plant is very susceptible to injury from arsenicals, and care must be exercised in their use. Best results for its control have been obtained with magnesium arsenate, applied as a spray at the rate of 2 pounds to 100 gallons of water, or about 2 pounds per acre, on bush beans drilled in rows 3 feet apart. This arsenical is safe for application to bean foliage and at the same time is sufficiently toxic to kill larvæ and some adults. Caseinate of lime may be used as a spreader at the rate of 1 pound to 100 gallons of spray. About 90 to 100 gallons of spray are required per acre when a large machine is used which directs three nozzles to each row. Two of the nozzles should be directed so that the spray will reach the under side of the leaves. The third nozzle should be directed to the tops of the plants. While this third nozzle is not absolutely necessary, best results have been obtained where three nozzles were used. The spray should be applied at 150 pounds pressure or higher.

Where spraying is impracticable because of lack of water facilities or for other reasons, good results may be obtained by the thorough application of a dust consisting of 1 part of high-grade calcium arsenate and 9 parts of hydrated lime. On small acreages a knapsack bellows duster with a spout attached to a flexible hose is satisfactory. This dust should be applied to the under side of the leaves at the rate of about 15 pounds per acre. Similar results have followed the use of a mixture consisting of 1 part of dry calcium arsenate, 1 part of fine dusting sulphur, and 4 parts of hydrated lime. Dust mixtures can be prepared on the farm more economically than they can be purchased.

Heavily infested fields should be plowed under as soon as the crop is picked. The grower should not plant more beans than he can treat properly. Treatment should begin as soon as the eggs of the bean beetle become numerous, usually at about the time the third true leaf appears on the plant. From one to five applications are required, depending on the degree of infestation, whether light or heavy.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE.

July 26, 1924.

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